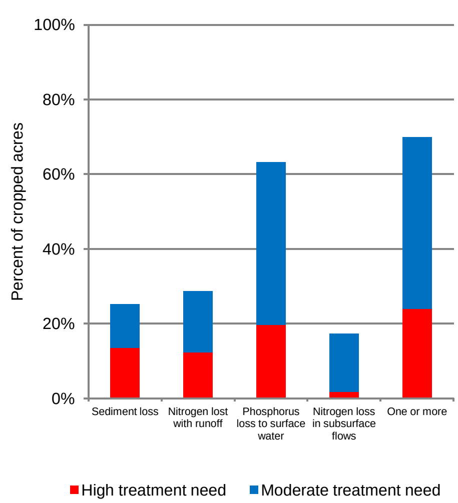
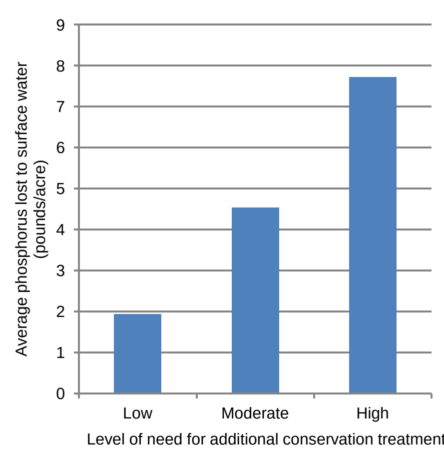
United States Department of Agriculture
Natural Resources Conservation Service

Conservation Effects Assessment Project (CEAP)

NOVEMBER 2011

Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Ohio-Tennessee River Basin





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Cover photos are by (clockwise from top left) **Tim McCabe, Tim McCabe, Lynn Betts, Tim McCabe,** USDA Natural Resources Conservation Service**.**

CEAP—Strengthening the science base for natural resource conservation

The Conservation Effects Assessment Project (CEAP) was initiated by USDA's Natural Resources Conservation Service (NRCS), Agricultural Research Service (ARS), and Cooperative State Research, Education, and Extension Service (CSREES—now National Institute of Food and Agriculture [NIFA]) in response to a general call for better accountability of how society would benefit from the 2002 Farm Bill's substantial increase in conservation program funding (Mausbach and Dedrick 2004). The original goals of CEAP were to estimate conservation benefits for reporting at the national and regional levels and to establish the scientific understanding of the effects and benefits of conservation practices at the watershed scale. As CEAP evolved, the scope was expanded to provide research and assessment on how to best use conservation practices in managing agricultural landscapes to protect and enhance environmental quality.

CEAP activities are organized into three interconnected efforts:

- *Bibliographies, literature reviews, and scientific workshops* to establish what is known about the environmental effects of conservation practices at the field and watershed scale.
- *National and regional assessments* to estimate the environmental effects and benefits of conservation practices on the landscape and to estimate conservation treatment needs. The four components of the national and regional assessment effort are *Cropland*; *Wetlands*; *Grazing lands*, including rangeland, pastureland, and grazed forest land; and *Wildlife*.
- *Watershed studies* to provide in-depth quantification of water quality and soil quality impacts of conservation practices at the local level and to provide insight on what practices are the most effective and where they are needed within a watershed to achieve environmental goals.

Research and assessment efforts were designed to estimate the effects and benefits of conservation practices through a mix of research, data collection, model development, and model application. Duriancik et al. (2008) summarize the accomplishments of CEAP through 2007. A vision for how CEAP can contribute to better and more effective delivery of conservation programs in the years ahead is addressed in Maresch, Walbridge, and Kugler (2008). Additional information on the scope of the project can be found at http://www.nrcs.usda.gov/technical/nri/ceap/.

This report was prepared by the Conservation Effects Assessment Project (CEAP) Cropland Modeling Team and published by the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). The modeling team consists of scientists and analysts from NRCS, the Agricultural Research Service (ARS), Texas AgriLife Research, and the University of Massachusetts.

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Acknowledgements

The team thanks Al**ex Barbarika**, **Rich Iovanna**, and **Skip Hyberg** USDA-Farm Service Agency, for providing data on Conservation Reserve Program (CRP) practices and making contributions to the report; **Harold Coble and Danesha Carley**, North Carolina State University, for assisting with the analysis of the integrated pest management (IPM) survey data; **Dania Fergusson, Eugene Young,** and **Kathy Broussard**, USDA-National Agricultural Statistics Service, for leading the survey data collection effort; **Mark Siemers** and **Todd Campbell**, CARD, Iowa State University, for providing I-APEX support; **NRCS field offices** for assisting in collection of conservation practice data; **Dean Oman**, USDA-NRCS, Beltsville, MD, for geographic information systems (GIS) analysis support; **Melina Ball**, Texas AgriLife Research, Temple, TX, for HUMUS graphics support; **Peter Chen, Susan Wallace, George Wallace, and Karl Musser,** Paradigm Systems, Beltsville, MD, for graphics support, National Resources Inventory (NRI) database support, Web site support, and calculation of standard errors; and many others who provided advice, guidance, and suggestions throughout the project.

The team also acknowledges the many helpful and constructive suggestions and comments by reviewers who participated in the peer review of earlier versions of the report.

Foreword

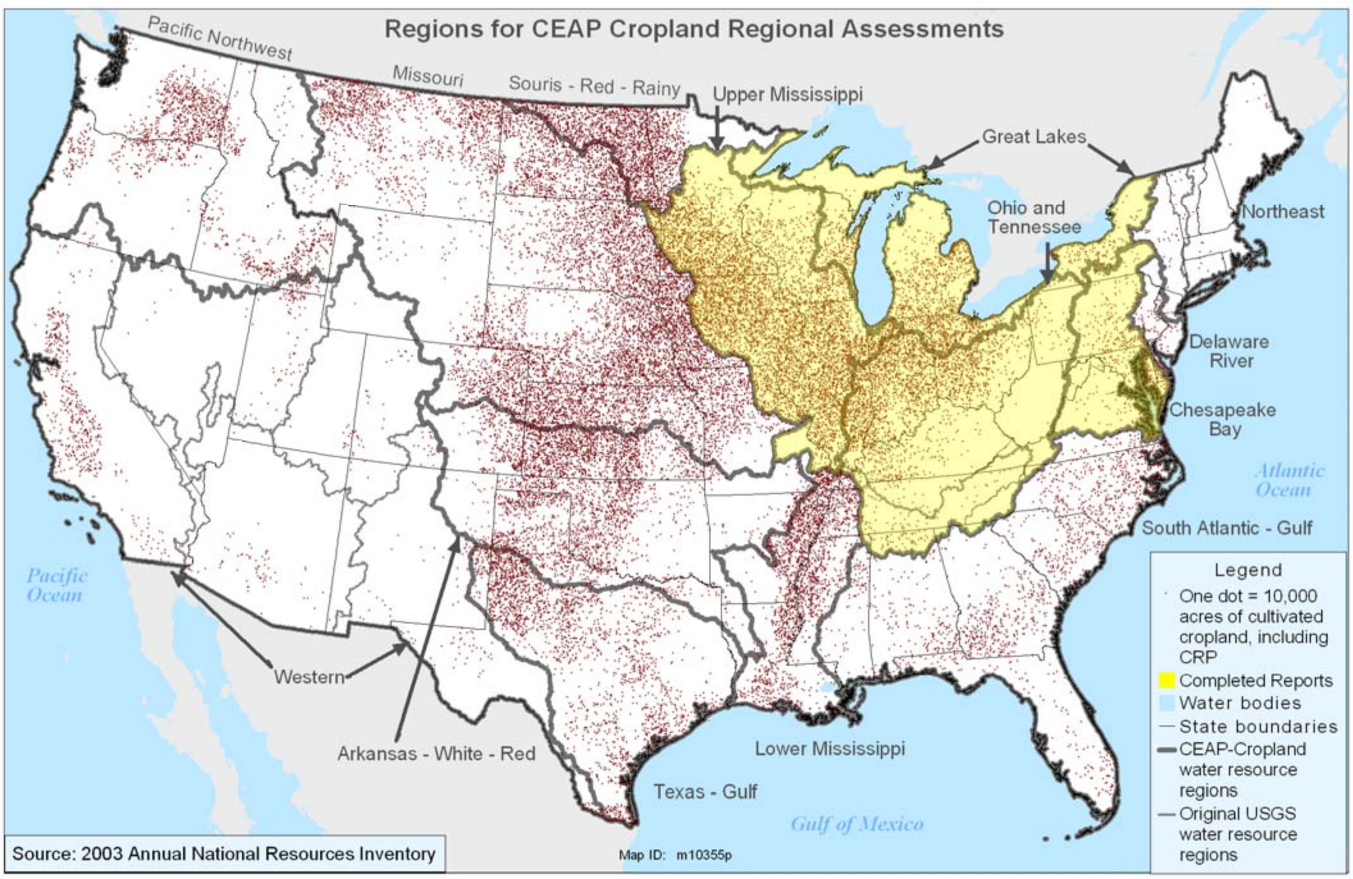
The United States Department of Agriculture has a rich tradition of working with farmers and ranchers to enhance agricultural productivity and environmental protection. Conservation pioneer Hugh Hammond Bennett worked tirelessly to establish a nationwide Soil Conservation Service along with a system of Soil and Water Conservation Districts. The purpose of these entities, now as then, is to work with farmers and ranchers and help them plan, select, and apply conservation practices to enable their operations to produce food, forage, and fiber while conserving the Nation's soil and water resources.

USDA conservation programs are voluntary. Many provide financial assistance to producers to help encourage adoption of conservation practices. Others provide technical assistance to design and install conservation practices consistent with the goals of the operation and the soil, climatic, and hydrologic setting. By participating in USDA conservation programs, producers are able to—

- install structural practices such as riparian buffers, grass filter strips, terraces, grassed waterways, and contour farming to reduce erosion, sedimentation, and nutrients leaving the field;
- adopt conservation systems and practices such as conservation tillage, comprehensive nutrient management, integrated pest management, and irrigation water management to conserve resources and maintain the long-term productivity of crop and pasture land; and
- retire land too fragile for continued agricultural production by planting and maintaining on them grasses, trees, or wetland vegetation.

Once soil conservation became a national priority, assessing the effectiveness of conservation practices also became important. Over the past several decades, the relationship between crop production and the landscape in which it occurs has become better understood in terms of the impact on sustainable agricultural productivity and the impact of agricultural production on other ecosystem services that the landscape has potential to generate. Accordingly, the objectives of USDA conservation policy have expanded along with the development of conservation practices to achieve them.

This report on the Ohio-Tennessee River Basin is the fourth in a series of regional reports that continues the tradition within USDA of assessing the status, condition, and trends of natural resources to determine how to improve conservation programs to best meet the Nation's needs. These reports use a sampling and modeling approach to quantify the environmental benefits that farmers and conservation programs are currently providing to society, and explore prospects for attaining additional benefits with further conservation treatment. Subsequent reports on cultivated cropland will be prepared for regions shown in the following map.



Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Ohio-Tennessee River Basin

Contents

Documentation Reports

There are a series of documentation reports and associated publications by the modeling team posted on the CEAP website at: http://www.nrcs.usda.gov/technical/nri/ceap. (Click on "Cropland" and then click on "documentation reports and associated publications.") Included are the following reports that provide details on the modeling and databases used in this study:

- The HUMUS/SWAT National Water Quality Modeling System and Databases
- Calibration and Validation of CEAP-HUMUS
- Delivery Ratios Used in CEAP Cropland Modeling
- APEX Model Validation for CEAP
- Pesticide Risk Indicators Used in CEAP Cropland Modeling
- Integrated Pest Management (IPM) Indicator Used in CEAP Cropland Modeling
- NRI-CEAP Cropland Survey Design and Statistical Documentation
- Transforming Survey Data to APEX Model Input Files
- Modeling Structural Conservation Practices for the Cropland Component of the National Conservation Effects Assessment Project
- APEX Model Upgrades, Data Inputs, and Parameter Settings for Use in CEAP Cropland Modeling
- APEX Calibration and Validation Using Research Plots in Tifton, Georgia
- The Agricultural Policy Environmental EXtender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses
- The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions
- Historical Development and Applications of the EPIC and APEX Models
- Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment
- Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT modeling
- Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling

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Executive Summary

Agriculture in the Ohio-Tennessee River Basin

The Ohio-Tennessee River Basin consists of two of the six water resource regions that make up the Mississippi River drainage. The Tennessee River joins the Ohio River near the confluence of the Ohio and Mississippi near Paducah, Kentucky. The Ohio-Tennessee River Basin covers about 204,000 square miles and includes a significant portion of seven states— Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee, and West Virginia—and small parts of seven additional states.

Agricultural land makes up about 39 percent of the land base in this basin—21 percent cultivated cropland and 18 percent permanent hayland and grazing land. About 9 percent of the land base is urban land. The remaining land area is primarily forested. The northwestern part of the basin (Illinois, Indiana, and Ohio) is intensively cropped, with more than half of the land base in cultivated cropland. Cultivated cropland represents less than 10 percent of the area in the eastern and southern parts of the basin.

Agriculture plays an important role in the economy of the region. The value of agricultural sales in 2007 was about $22 billion—about half from crop production and half from livestock production. Corn and soybeans are the principal crops grown. Livestock sales are dominated by poultry and eggs—$3.8 billion in 2007, representing 10 percent of sales nationally. Livestock operations in the region also produced 9 percent of all hog and pig sales in the United States in 2007and 6 percent of all dairy sales.

The 2007 Census of Agriculture reported that there were about 344,500 farms in the region—16 percent of the farms in the United States. Most of the farms (81 percent) in 2007 were small operations with less than $50,000 in total farm sales. About 4 percent of the farms had total farm sales greater than $500,000. About 52 percent of the farms primarily raise crops, about 42 percent are primarily livestock operations, and the rest produce a mix of livestock and crops.

Focus of CEAP Study Is on Edge-Of-Field Losses from Cultivated Cropland

The primary focus of the CEAP Ohio-Tennessee River Basin study is on the 21 percent of the watershed that is cultivated cropland. The study was designed to—

- quantify the effects of conservation practices commonly used on cultivated cropland in the Ohio-Tennessee River Basin during 2003–06,
- evaluate the need for additional conservation treatment in the region on the basis of edge-of-field losses, and
- estimate the potential gains that could be attained with additional conservation treatment.

The assessment uses a statistical sampling and modeling approach to estimate the effects of conservation practices. The National Resources Inventory, a statistical survey of conditions and trends in soil, water, and related resources on U.S. non-Federal land conducted by USDA's Natural Resources Conservation Service, provides the statistical framework. Physical process simulation models were used to estimate the effects of conservation practices that were in use during the period 2003–06. Information on farming activities and conservation practices was obtained primarily from a farmer survey conducted as part of the study. The assessment includes not only practices associated with Federal conservation programs but also the conservation efforts of States, independent organizations, and individual landowners and farm operators. The analysis assumes that structural practices (such as buffers, terraces, and grassed waterways) reported in the farmer survey or obtained from other sources were appropriately designed, installed, and maintained.

The assessment was done using a common set of criteria and protocols applied to all regions in the country to provide a systematic, consistent, and comparable assessment at the national level. The sample size of the farmer survey—18,700 sample points nationally with 2,124 sample points in the Ohio-Tennessee River Basin—is sufficient

for reliable and defensible reporting at the regional scale with some reporting for large watersheds within the region, but is generally insufficient for assessments of smaller areas within the region.

Voluntary, Incentives-Based Conservation Approaches Are Achieving Results

Results from the farmer survey show that farmers in the Ohio-Tennessee River Basin have made significant progress in reducing sediment, nutrient, and pesticide losses from farm fields through conservation practice adoption.

Conservation Practice Use

The farmer survey found, for the period 2003–06, that producers use either residue and tillage management practices or structural practices, or both, on 98 percent of the acres.

- Structural practices for controlling water erosion are in use on 40 percent of cropped acres. Twenty-seven percent of cropped acres are designated as highly erodible land; structural practices designed to control water erosion are in use on 59 percent.
- Reduced tillage is common in the region; 93 percent of the cropped acres meet criteria for either no-till (52 percent) or mulch till (41 percent). All but 4 percent of the acres had evidence of some kind of reduced tillage on at least one crop in the rotation.

The farmer survey also found that most acres have evidence of some nitrogen or phosphorus management.

- Appropriate *timing* of nitrogen applications is in use on about 64 percent of the acres for all crops in the rotation, and appropriate *timing* of phosphorus applications is in use on about 61 percent of the acres for all crops in the rotation.
- Appropriate *rates* of nitrogen application are in use on about 39 percent of the acres for all crops in the rotation, and appropriate *rates* of phosphorus application are in use on about 43 percent of the acres for all crops in the rotation.

There was less evidence, however, of consistent use of appropriate rates, timing, *and* method of nutrient application on each crop in every year of production.

- Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production are in use on only about 17 percent of cropped acres.
- Appropriate phosphorus management practices (appropriate rate, timing, and method) are in use on 21 percent of the acres on all crops during every year of production.
- Only about 10 percent of cropped acres meet full nutrient management criteria for *both* phosphorus and nitrogen management.

About 66 percent of cropped acres are gaining soil organic carbon. An additional 20 percent of cropped acres are considered to be “maintaining” soil organic carbon (average annual loss less than 100 pounds per acre). Overall, 86 percent of cropped acres are maintaining or enhancing soil organic carbon.

Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of 776,400 acres in the region, of which 70 percent is highly erodible land.

Conservation Accomplishments

Compared to a model scenario without conservation practices, field-level model simulations showed that conservation practice use during the period 2003–06 has—

- reduced wind erosion by 60 percent;
- reduced waterborne sediment loss from fields by 52 percent;
- reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 35 percent;
- reduced nitrogen loss in subsurface flows by 11 percent;
- reduced total phosphorus loss (all loss pathways) from fields by 33 percent;
- reduced pesticide loss from fields to surface water, resulting in a 19-percent reduction in edge-of-field pesticide risk (all pesticides combined) for humans and a 29-percent reduction for aquatic ecosystems; and
- increased the percentage of cropped acres gaining soil organic carbon from 57 to 66.

For land in long-term conserving cover (776,400 acres), soil erosion and sediment loss have been almost completely eliminated. Compared to a cropped condition without conservation practices, average annual total nitrogen loss has been reduced by 80 percent, average annual total phosphorus loss has been reduced by 93 percent, and soil organic carbon has been increased by an average of 497 pounds per acre per year.

Reductions in field-level losses due to conservation practices, including land in long-term conserving cover, are expected to improve water quality in streams and rivers in the region. Edge-of-field losses of sediment, nitrogen, phosphorus, and the pesticide atrazine were incorporated into a national water quality model to estimate the extent to which conservation practices have reduced amounts of these contaminants delivered to rivers and streams throughout the region. Transport of sediment, nutrients, and pesticides from farm fields to streams and rivers involves a variety of processes and time-lags, and not all of the potential pollutants leaving fields contribute to instream loads.

The model simulations showed that conservation practices in use during the period 2003–06 have reduced average annual loads delivered to rivers and streams within the basin, compared to a no-practice scenario, by 55 percent for sediment, 26 percent for nitrogen, 32 percent for phosphorus, and 18 percent for atrazine. The national water quality model also provided estimates of reductions in ***instream loads*** due to conservation practice use. *When considered along with loads from all other sources*, conservation practices in use on cultivated cropland in 2003–06 have reduced total instream loads delivered from the region to the Mississippi River by—

- 16 percent for sediment,
- 15 percent for nitrogen,
- 21 percent for phosphorus, and
- 18 percent for atrazine.

Opportunities Exist to Further Reduce Sediment and Nutrient Losses from Cultivated Cropland

The assessment of conservation treatment needs presented in this study identifies significant opportunities to further reduce contaminant losses from farm fields. The study found that 24 percent of cropped acres (6.0 million acres) have a **high** level of need for additional conservation treatment. Acres with a **high** level of need consist of the most vulnerable acres with the least conservation treatment and the highest losses of sediment or nutrients. An additional 46 percent of cropped acres (11.5 million acres) have a **moderate** need for additional conservation treatment. The remaining cropped acres (7.5 million acres) have a **low** need for additional treatment, and are considered to be adequately treated.

Model simulations show that adoption of additional erosion control and nutrient management practices on the 17.5 million acres with a **high** or **moderate** treatment need would, compared to the 2003–06 baseline, further reduce edge-of-field sediment loss by 83 percent, losses of nitrogen with surface runoff by 58 percent, losses of nitrogen in subsurface flows by 37 percent, and losses of phosphorus (sediment-attached and soluble) by 61 percent. These field-level reductions would, in turn, further reduce ***instream loads***. Relative to the 2003–06 baseline, this level of additional conservation treatment would reduce total ***instream loads*** *delivered from the region to the Mississippi River from all sources* by—

- 15 percent for sediment,
- 20 percent for nitrogen,
- 31 percent for phosphorus, and
- 11 percent for atrazine.

Emerging technologies not evaluated in this study promise to provide even greater conservation benefits once their use becomes more widespread. These include—

- Innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies and improved manure application equipment;
- Enhanced-efficiency nutrient application products such as slow or controlled release fertilizers, polymer coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- Drainage water management that controls discharge of drainage water and treats contaminants, thereby reducing the levels of nitrogen and even some soluble phosphorus loss;

- Constructed wetlands receiving surface water runoff and drainage water from farm fields prior to discharge to streams and rivers; and
- Improved crop genetics that increase yields without increasing nutrient inputs.

Comprehensive Conservation Planning and Implementation Are Essential

The most critical conservation concern related to cropland in the region is the need to reduce phosphorus losses from farm fields. About 20 percent of the acres in the region have a **high** need for additional nutrient management to address this concern, and an additional 43 percent have a **moderate** need. The proportion of cropped acres with a **high** or **moderate** need for additional conservation treatment for other resource concerns was determined to be—

- 25 percent for sediment loss (13.5 percent with a **high** need for treatment),
- 29 percent for nitrogen loss with runoff (12 percent with a **high** need for treatment), and
- 17 percent for nitrogen loss in subsurface flows (2 percent with a **high** need for treatment).

While conservation practice use has been effective in reducing phosphorus loss from fields, phosphorus loss to surface water in the region remains high. With the conservation practices in use as represented by the 2003–06 baseline, about 35 percent of cropped acres exceed 4 pounds per acre per year, on average. This is, in part, because of high levels of *soluble* phosphorus loss, which averages 2.4 pounds per acre per year in the baseline. Soluble phosphorus loss with surface water runoff and through lateral flow (including discharge to drainage tiles and ditches) was the dominant loss pathway for 57 percent of cropped acres in the region.

Additional conservation is also needed to control surface water runoff and erosion in the region. One-fourth of the acres with a **high** or **moderate** need for treatment need additional treatment for sediment loss and nitrogen and phosphorus runoff loss.

The high losses of soluble phosphorus and nitrogen in subsurface flows in the region can be addressed with complete and consistent use of nutrient management—appropriate rate, form, timing, *and* method of application. This is especially important for acres that have or need soil erosion control. Structural erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil, re-routing the nitrogen and soluble phosphorus from surface to subsurface loss pathways.

A ***comprehensive conservation planning process*** is required to identify the appropriate combination of nutrient management techniques and soil erosion control practices needed to simultaneously address soil erosion, soluble phosphorus losses, nitrogen losses in runoff, *and* loss of nitrogen in subsurface flows. A field with adequate conservation practice use will have a suite of practices that addresses all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses through the dominant loss pathways.

Targeting Enhances Effectiveness and Efficiency

Targeting program funding and technical assistance for accelerated treatment of acres with the most critical need for additional treatment is the most efficient way to reduce agricultural sources of contaminants from farm fields.

Not all acres provide the same benefit from conservation treatment. The more vulnerable acres, such as highly erodible land and soils prone to leaching, inherently lose more sediment or nutrients; therefore greater benefit can be attained with additional conservation treatment. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

The least treated acres also provide greater benefits from treatment, especially if they are also inherently vulnerable to runoff or leaching. The farmer survey showed that, while most acres benefit from some use of conservation practices, environmentally “risky” management is still used on some acres (such as fall application of commercial fertilizers and manure, surface broadcast applications of commercial fertilizers and manure, and conventional tillage).

Use of additional conservation practices on acres that have a **high** need for additional treatment—acres most prone to runoff or leaching and with low levels of conservation practice use—can reduce per-acre sediment and nutrient losses by about twice as much as treatment of acres with a **moderate** conservation treatment need. Even greater efficiencies are realized when acres with either a **high** or **moderate** need for additional treatment are compared to per-acre benefits for acres with a **low** need for additional treatment.

For example, model simulations of additional treatment in the Ohio-Tennessee River Basin demonstrated that phosphorus loss to surface water would be reduced by an average of 5.9 pounds per acre per year on the 6.0 million acres with a **high** need for additional treatment, compared to 3.0 pounds per acre per year for additional treatment of the 11.5 million acres with a **moderate** need for additional treatment. The reduction in phosphorus loss would average only 0.8 pound per acre per year for treatment of the 7.5 million acres with a **low** need for additional treatment, on average.

Effects of Conservation Practices on Ecological Conditions Are Beyond the Scope of This Study

Ecological outcomes are not addressed in this report, nor were the estimates of conservation treatment needs specifically derived to attain Federal, State, or local water quality goals within the region.

Ecosystem impacts related to water quality are specific to each water body. Water quality goals also depend on the designated uses for each water body. In order to understand the effects of conservation practices on water quality in streams and lakes, it is first necessary to understand what is happening in the receiving waters and then evaluate whether the practices are having the desired effect on the current state of that aquatic ecosystem.

The regional scale of the design of this study precludes these kinds of assessments.

The primary focus of this report is on losses of potential pollutants from farm fields and prospects for attaining further loss reductions with additional soil erosion control and nutrient management practices. Conservation treatment needs were estimated to achieve "full treatment" from the field-level perspective, rather than to reduce instream loads to levels adequate for designated water uses. The simulated treatment levels were designed to minimally affect crop yields and maintain regional production capacity for food, fiber, forage, and fuel.

From this perspective, a field with adequate conservation treatment will have combinations of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses. For purposes of this report, "full treatment" consists of a suite of practices that—

- *avoid* or limit the potential for contaminant losses by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- *control* overland flow where needed; and
- *trap* materials leaving the field using appropriate edge-of-field mitigation.

This field-based concept of "full conservation treatment" will likely be sufficient to protect water quality for some environmental settings. For more sensitive environmental settings, however, it may be necessary to adopt even stricter management criteria and techniques such as widespread use of cover crops, drainage water management, conservation rotations with fewer row crop years, or emerging production and conservation technologies. In some cases, attainment of water quality goals may even require watershed-scale solutions, such as sedimentation basins, wetland construction, streambank restoration, or an increased proportion of acres in long-term conserving cover.

Chapter 1
Land Use and Agriculture in the Ohio-Tennessee River Basin

Land Use

The Ohio-Tennessee River Basin covers about 204,000 square miles and includes parts of 14 states. A significant portion of seven states are included in the region—Ohio, Indiana, Kentucky, Tennessee, Illinois, West Virginia, and Pennsylvania. Also included in the region are small parts of Virginia, Georgia, North Carolina, Alabama, Mississippi, Maryland, and New York.

Half of the land cover in the Ohio-Tennessee River Basin is forest land, primarily deciduous forests (table 1 and fig. 1). Cultivated cropland accounts for 21 percent of the area, and permanent pastureland and hay land account for 15 percent. Urban areas make up about 9 percent of the area—major metropolitan areas center around Cincinnati, Dayton, and Columbus, Ohio; Pittsburgh, Pennsylvania; Indianapolis, Indiana; and Nashville, Tennessee. Water, wetlands, rangeland, and other land covers make up the remaining 5 percent of the area.

Illustrated in figure 1, over 90 percent of the cropped acres in the region are in four of the 14 states—Indiana (38 percent of cropped acres), Ohio (23 percent), Illinois (19 percent), and Kentucky (11 percent).

Table 1. Distribution of land cover in the Ohio-Tennessee River Basin

Land use	Acres*	Percent including water	Percent excluding water
Cultivated cropland and land enrolled in the CRP General Signup**	26,825,225	21	21
Hayland not in rotation with crops	7,354,922	6	6
Pastureland not in rotation with crops	11,806,752	9	9
Rangeland--grass	2,911,496	2	2
Rangeland-- brush	1,189,616	1	1
Horticulture	174,651	<1	<1
Forestland			
Deciduous	59,416,414	46	46
Evergreen	3,257,565	2	3
Mixed	2,708,697	2	2
Urban	11,563,365	9	9
Wetlands			
Forested	799,714	1	1
Non-Forested	138,773	<1	<1
Barren	319,808	<1	<1
Subtotal	128,466,998	99	100
Water	1,922,776	1	--
Total	130,389,774	100	--

Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007).
*Acreage estimates for cultivated cropland differ slightly from those based on the NRI-CEAP sample because of differences in data sources and estimation procedures. Acres enrolled in the CRP General Signup are used to represent land in long-term conserving cover.
**Includes hayland and pastureland in rotation with crops.

Agriculture

The 2007 Census of Agriculture reported 344,500 farms in the Ohio-Tennessee River Basin, about 16 percent of the total number of farms in the United States (table 2). Farms in the Ohio-Tennessee River Basin make up about 6 percent of all farmland in the nation. According to the 2007 Census of Agriculture, the value of Ohio-Tennessee River Basin agricultural sales in 2007 was about $22 billion—about half from crops and half from livestock.

About 52 percent of Ohio-Tennessee River Basin farms primarily raise crops, about 42 percent are primarily livestock operations, and the rest produce a mix of livestock and crops (table 3).

Farms in this region are typically small operations. Most of the farms (81 percent) in 2007 had less than $50,000 in total farm sales. Only 4 percent of the farms had total farm sales greater than $500,000 (table 3). Forty-two percent of the farms in the Ohio-Tennessee River Basin are smaller than 50 acres, and 51 percent are between 50 and 500 acres. Only 7 percent of the farms have more than 500 acres (table 3). The average number of acres per farm in the region is 169 acres, compared to a national average of 418 acres.

Crop production

The Ohio-Tennessee River Basin accounts for about 8 percent of all U.S. crop sales (table 2). Corn and soybeans are the principal crops grown. Wheat and hay are important secondary crops in terms of acres harvested. Tobacco is an important cash crop in some parts of the region; tobacco sales totaled $396 million in 2007, representing 31 percent of national tobacco sales.

Farmers in the region produced 13 percent of the corn harvested for grain in the United States in 2007 (1.6 billion bushels on 11.4 million acres) and 15 percent of the soybeans harvested (389 million bushels on 9.6 million acres). Hay was harvested on 6.9 million acres.

Commercial fertilizers and pesticides are widely used on agricultural land in the region (table 2). In 2007, 22 million acres of cropland were fertilized, 21 million acres of cropland and pasture were treated with chemicals for weed control, and 7 million acres of hay and cropland were treated for insect control. About 2.3 million acres had manure applied in 2007. Irrigation was used on about 415,000 acres to supplement rainfall during dry periods.

Livestock operations

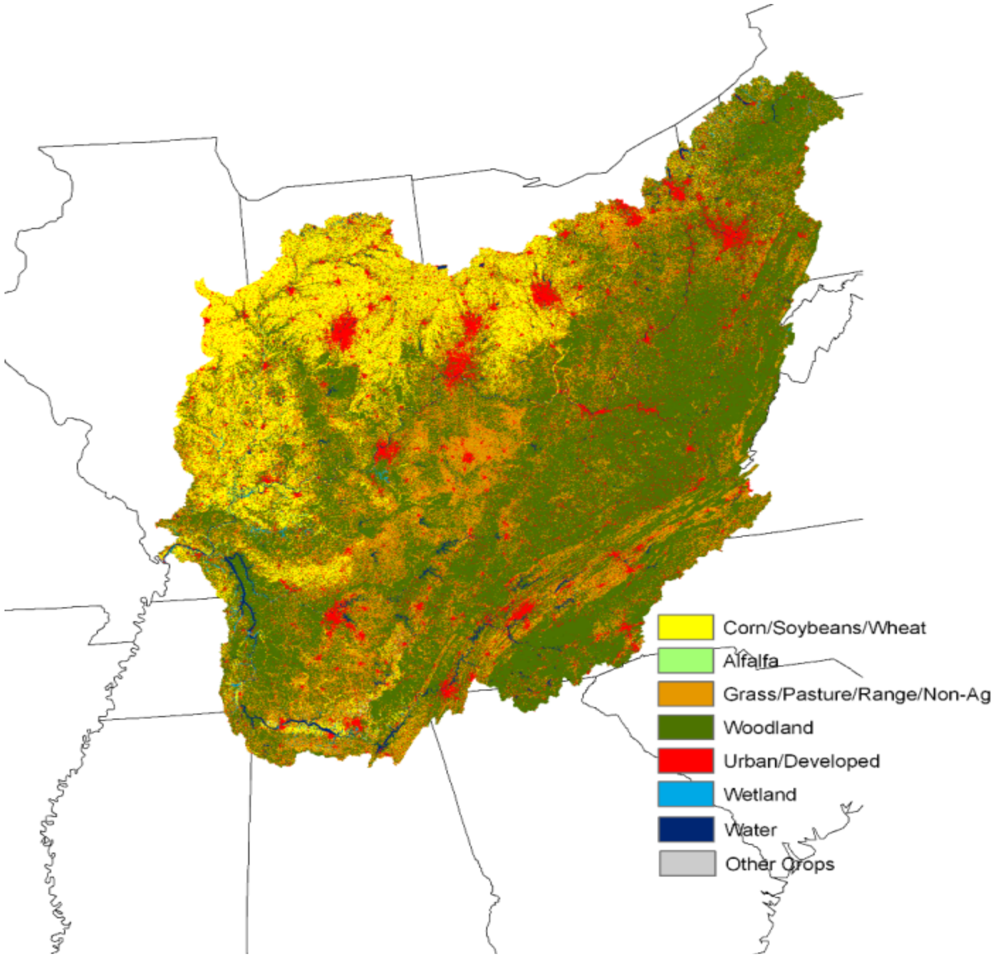
Livestock sales in the region are dominated by poultry and egg sales, which totaled $3.8 billion in 2007 and represented 10 percent of all poultry and egg sales nationally (table 2). In terms of animal units, however, livestock populations in the region are dominated by pastured livestock—cattle, horses, sheep, and goats. (An animal unit is 1,000 pounds of live animal weight.) Livestock operations in the region also produced 9 percent of all hog and pig sales in the United States in 2007 and 6 percent of all dairy sales (table 2).

Table 2. Profile of farms in the Ohio-Tennessee River Basin, 2007

Characteristic	Value	Percent of national total
Number of farms	344,536	16
Acres on farms	58,212,992	6
Average acres per farm	169	
Cropland harvested, acres	30,093,394	10
Cropland used for pasture, acres	3,687,928	10
Cropland on which all crops failed, acres	335,976	5
Cropland in summer fallow, acres	87,511	1
Cropland idle or used for cover crops, acres	1,839,656	5
Woodland pastured, acres	2,784,348	10
Woodland not pastured, acres	7,552,404	16
Permanent pasture and rangeland, acres	9,381,210	2
Other land on farms, acres	2,450,565	8
Principal crops grown		
Field corn for grain harvested, acres	11,379,454	13
Field corn for silage harvested, acres	463,342	8
Soybeans harvested, acres	9,613,569	15
Wheat harvested, sum acres	1,125,608	2
Alfalfa hay harvested, acres	1,064,647	5
Tame and wild hay harvested, acres	5,835,733	17
Irrigated harvested land, acres	415,490	1
Irrigated pastureland or rangeland, acres	6,716	0
Cropland fertilized, acres	22,241,445	9
Pastureland fertilized, acres	3,119,864	12
Land treated for insects on hay or other crops, acres	7,337,161	8
Land treated for nematodes in crops, acres	561,317	7
Land treated for diseases in crops and orchards, acres	1,217,601	5
Land treated for weeds in crops and pasture, acres	20,690,147	9
Crops on which chemicals for defoliation applied, acres	253,695	2
Acres on which manure was applied	2,261,535	10
Total grains and oilseeds sales, million dollars	8,844,315,224	11
Total fruit and berry sales, million dollars	106,994,313	1
Total vegetable, melons sales, million dollars	269,922,408	2
Total nursery, greenhouse, and floriculture sales, million dollars	960,359,829	6
Total tobacco sales	395,873,648	31
Total hay and other crop sales, million dollars	484,223,491	3
Total crop sales, million dollars	11,061,688,913	8
Total dairy sales, million dollars	1,794,574,968	6
Total hog and pigs sales, million dollars	1,584,627,012	9
Total poultry and eggs sales, million dollars	3,786,653,666	10
Total cattle sales, million dollars	2,857,378,369	5
Total sheep, goats, and their products sales, million dollars	42,231,379	6
Total horses, ponies, and mules sales, million dollars	1,032,904,455	50
Total other livestock sales, million dollars	312,112,757	12
Total livestock sales, million dollars	11,410,482,606	7
Animal units on farms		
All livestock types	8,695,529	8
Swine	897,016	9
Dairy cows	798,849	6
Fattened cattle	214,648	2
Other cattle, horses, sheep, goats	5,996,405	10
Chickens, turkeys, and ducks	767,896	10
Other livestock	20,715	5

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA
Note: Information in the Census of Agriculture was used to estimate animal units using methods and assumptions described in USDA-NRCS (2003).

Figure 1. Land cover in the Ohio-Tennessee River Basin



Source: National Agricultural Statistics Service (NASS 2007).

Table 3. Characteristics of farms in the Ohio-Tennessee River Basin, 2007

	Number of farms	Percent of farms in Ohio-Tennessee River Basin
Farming primary occupation	140,839	41
Farm size:		
<50 acres	145,322	42
50–500 acres	176,339	51
500–2,000 acres	20,220	6
>2,000 acres	2,655	1
Farm sales:		
<$10,000	207,895	60
$10,000–50,000	73,754	21
$50,000–250,000	37,853	11
$250,000–500,000	11,179	3
>$500,000	13,855	4
Farm type:		
Crop sales make up more than 75% of farm sales	178,973	52
Livestock sales make up more than 75% of farm sales	143,089	42
Mixed crop and livestock sales	22,474	7
Farms with no livestock sales	120,201	35
Farms with few livestock or specialty livestock types	116,309	34
Farms with pastured livestock and few other livestock types	85,418	25
Farms with animal feeding operations (AFOs)*	22,608	7

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA
* AFOs, as defined here, typically have a total of more than 12 animal units consisting of fattened cattle, dairy cows, hogs and pigs, chickens, ducks, and turkeys.

Although about two-thirds of the farms in the Ohio-Tennessee River Basin (224,000 farms) reported livestock sales in 2007, about half of these farms had fewer than 30 animal units on the farm; a small number of these farms had specialty livestock such as rabbits, pheasants, mink, or deer (table 3). Pastured livestock (cattle, horses, sheep, or goats) predominate on about 85,000 farms. Only about 23,000 of the farms in the region (7 percent) could be defined as animal feeding operations (AFOs). AFOs are livestock operations typically with confined poultry, swine, or cattle. The bulk of these are also small operations. Only about 3,500 of the livestock operations (16 percent of the AFOs) are relatively large, with livestock numbers in 2007 above the EPA minimum threshold for a small concentrated animal feeding operation (CAFO).

Watersheds

A hydrologic accounting system consisting of water resource regions, major subregions, and smaller watersheds has been defined by the U.S. Geological Survey (USGS) (1980). Each water resource region is designated with a 2-digit code, which is further divided into 4-digit subregions and then into 8-digit watersheds, or Hydrologic Unit Codes (HUCs). The Ohio-Tennessee River Basin is represented by 18 subregions.

Cultivated cropland is concentrated in seven of the 18 subregions. The percent of cultivated cropland in each of the 18 subregions is presented in figure 2 and in table 4. Over half of the area in three subregions is cultivated cropland—the Wabash-Patoka-White River Basin (subregion code 0512), the Great Miami Basin (subregion code 0508) and the Scioto River Basin (subregion code 0506). Two additional subregions have about one-fourth of the area in cultivated cropland—the Muskingum River Basin (subregion code 0504) and the Lower Ohio-Salt River Basin (subregion code 0514). The Green River Basin (subregion code 0511) and the Middle Ohio-Raccoon-Little-Miami (subregion code 0509) have 17 and 16 percent of the area in cultivated cropland, respectively.

About 85 percent of the cultivated cropland acres are in these seven subregions (table 4). The remaining subregions have less than 10 percent of the area in cultivated cropland. Six subregions in the eastern part of the basin have negligible amounts of cultivated cropland, each with less than 1 percent of the cultivated cropland in the region.

Figure 2. Percent cultivated cropland, including land in long-term conserving cover, for the 18 subregions in the Ohio-Tennessee River Basin

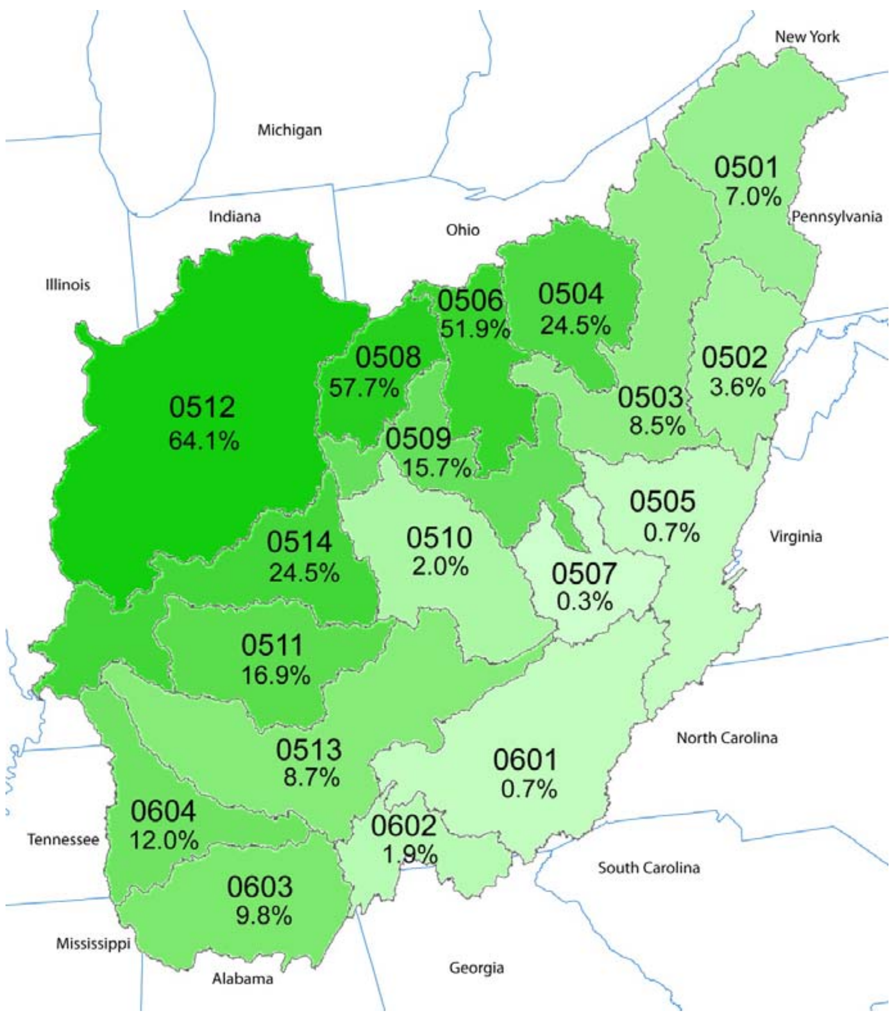


Table 4. Cultivated cropland use in the 18 subregions in the Ohio-Tennessee River Basin

Sub-region code	Subregion name	Total area (acres)	Cultivated cropland (acres)*	Percent cultivated cropland in subregion	Percent of cultivated cropland in Ohio-Tennessee River Basin	Percent of cultivated cropland acres in long-term conserving cover
	Ohio River Basin					
0501	Allegheny River Basin	7,480,223	523,673	7.0	2.0	2.0
0502	Monongahela River Basin	4,723,115	172,084	3.6	0.6	2.0
0503	Upper Ohio-Beaver-Little Kanawha	8,568,004	726,617	8.5	2.7	1.0
0504	Muskingum River Basin	5,144,483	1,258,752	24.5	4.7	2.0
0505	Kanawha River Basin	7,831,285	54,771	0.7	0.2	<0.1
0506	Scioto River Basin	4,172,019	2,166,250	51.9	8.1	4.7
0507	Guyandotte-Big Sandy River Basin	3,824,428	11,988	0.3	<0.1	<0.1
0508	Great Miami Basin	3,438,438	1,983,455	57.7	7.4	2.9
0509	Middle Ohio-Raccoon-Little-Miami	5,684,265	891,349	15.7	3.3	3.0
0510	Licking-Kentucky River Basin	6,825,391	136,355	2.0	0.5	<0.1
0511	Green River Basin	5,893,292	993,348	16.9	3.7	9.4
0512	Wabash-Patoka-White River Basin	21,092,009	13,516,353	64.1	50.4	2.7
0513	Upper and Lower Cumberland River Basin	11,472,712	998,487	8.7	3.7	7.1
0514	Lower Ohio-Salt River Basin	8,078,595	1,978,999	24.5	7.4	8.3
	Tennessee River Basin					
0601	Upper Tennessee including French Broad-Holston	11,050,500	78,609	0.7	0.3	<0.1
0602	Middle Tennessee including Hiwassee River	3,316,259	63,837	1.9	0.2	<0.1
0603	Middle Tennessee including Elk River	6,615,149	650,768	9.8	2.4	5.8
0604	Lower Tennessee-Duck River	5,179,608	619,532	12.0	2.3	21.3
	Total	130,389,774	26,825,225	20.6	100.0	4.1

Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007) and the 1997 National Resources Inventory (USDA-NRCS 2002).
* Acres of cultivated cropland include land in long-term conserving cover. Estimates of cultivated cropland were obtained from HUMUS databases on land use, differing slightly from acreage estimates obtained with the NRI-CEAP sample.
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Chapter 2
Overview of Sampling and Modeling Approach

Scope of Study

This study was designed to evaluate the effects of conservation practices at the regional scale to provide a better understanding of how conservation practices are benefiting the environment and to determine what challenges remain. The report does the following.

- Evaluates the extent of conservation practice use in the region in 2003-06;
- Estimates the environmental benefits and effects of conservation practices in use;
- Estimates conservation treatment needs for the region; and
- Estimates potential gains that could be attained with additional conservation treatment.

The study was designed to quantify the effects of commonly used conservation practices on cultivated cropland, regardless of how or why the practices came to be in use. This assessment is not an evaluation of Federal conservation programs, because it is not restricted to only those practices associated with Federal conservation programs.

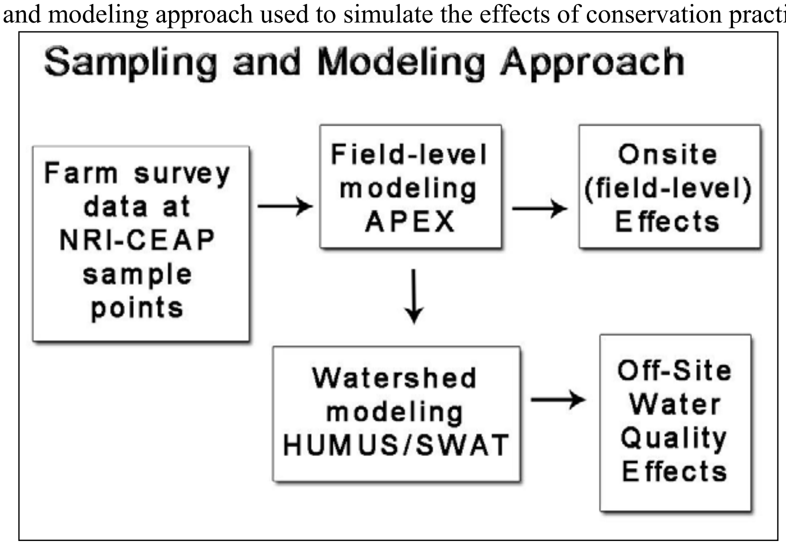
For purposes of this report, cultivated cropland includes land in row crops or close-grown crops (such as wheat and other small grain crops), hay and pasture in rotation with row crops and close-grown crops, and land in long-term conserving cover. Cultivated cropland does not include agricultural land that has been in hay, pasture, or horticulture for 4 or more consecutive years. Acres enrolled in the General Signup of the Conservation Reserve Program (CRP) were used to represent cultivated cropland currently in long-term conserving cover.

Sampling and Modeling Approach

The assessment uses a statistical sampling and modeling approach to estimate the environmental effects and benefits of conservation practices (fig. 3).

- A subset of 2,124 National Resources Inventory (NRI) sample points provides a statistical sample that represents the diversity of soils and other conditions for cropped acres in the Ohio-Tennessee River Basin. The sample also includes 559 additional NRI sample points designated as CRP acres to represent land in long-term conserving cover. NRI sample points are linked to NRCS Soil Survey databases and were linked spatially to climate databases for this study.
- A farmer survey—the NRI-CEAP Cropland Survey—was conducted at these sample points during the period 2003–06 to determine what conservation practices were in use and to collect information on farming practices.
- The field-level effects of the conservation practices were assessed using a field-scale physical process model—the Agricultural Policy Environmental Extender (APEX)—which simulates the day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of soil, nutrients, and pesticides.
- A watershed model and system of databases—the Hydrologic Unit Model for the United States (HUMUS)—was used to simulate how reductions of field losses have reduced instream concentrations and loadings of sediment, nutrients, and pesticides within the Ohio-Tennessee River Basin. The SWAT model (Soil and Water Assessment Tool) was used to simulate nonpoint source loadings from land uses other than cropland and to route instream loads from one watershed to another.

Figure 3. Statistical sampling and modeling approach used to simulate the effects of conservation practices



The modeling strategy for estimating the effects of conservation practices consists of two model scenarios that are produced for each sample point.

1. A baseline scenario, the "baseline conservation condition" scenario, provides model simulations that account for cropping patterns, farming activities, and conservation practices as reported in the NRI-CEAP Cropland Survey and other sources.
2. An alternative scenario, the "no-practice" scenario, simulates model results as if no conservation practices were in use but holds all other model inputs and parameters the same as in the baseline conservation condition scenario.

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios (fig. 4).[1] For example, to simulate "no practices" for sample points where some type of residue management is used, model simulations were conducted as if continuous conventional tillage had been used. Similarly, for sample points with structural conservation practices (buffers, terraces, grassed waterways, etc.), the no-practice scenario was simulated as if the practices were not present. The no-practice representation for land in long-term conserving cover was derived from model results for cropped acres as simulated in the no-practice scenario, representing how the land would have been managed had crops been grown without the use of conservation practices.

The approach captures the diversity of land use, soils, climate, and topography from the NRI; accounts for site-specific farming activities; estimates the loss of materials at the field scale where the science is most developed; and provides a statistical basis for aggregating results to the national and regional levels.[2]

[1] This modeling strategy is analogous to how the NRI produces estimates of soil erosion and the intrinsic erosion rate used to identify highly erodible land. The NRI uses the Universal Soil Loss Equation (USLE) to estimate sheet and rill erosion at each sample point on the basis of site-specific factors. Soil loss per unit area is equal to R*K*L*S*C*P. The first four factors—R, K, L, S—represent the conditions of climate, soil, and topography existing at a site. (USDA 1989). The last two factors—C and P—represent the degree to which management influences the erosion rate. The product of the first four factors is sometimes called the intrinsic, or potential, erosion rate. The intrinsic erosion rate divided by T, the soil loss tolerance factor, produces estimates of EI, the erodibility index. The intrinsic erosion rate is thus a representation of a "no-practice" scenario where C=1 represents smooth-tilled continuous fallow and P=1 represents no supporting practices.

[2] Previous studies have used this NRI micro-simulation modeling approach to estimate soil loss, nutrient loss, and change in soil organic carbon (Potter et al. 2006), to estimate pesticide loss from cropland (Kellogg et al. 1992, 1994, 2002; Goss et al. 1998), and to identify priority watersheds for water quality protection from nonpoint sources related to agriculture (Kellogg 2000, Kellogg et al. 1997).

Figure 4. Modeling strategy used to assess effects of conservation practices

The NRI and the CEAP Sample

The approach is an extension of the NRI, a longitudinal, scientifically-based survey designed to gauge natural resource status, conditions, and trends on the Nation's non-Federal land (Goebel 1998; USDA-NRCS 2002). NRCS has previously used the NRI for modeling to address issues related to natural resources and agriculture (Goebel and Kellogg 2002).
The NRI sampling design implemented in 1982 provided a stratified, two-stage, unequal probability area sample of the entire country (Goebel and Baker 1987; Nusser and Goebel 1997). Nominally square areas/segments were selected within geographical strata on a county-by-county basis; specific point locations were selected within each selected segment. The segments ranged in size from 40 to 640 acres but were typically half-mile square areas, and most segments contained three sample points. At each sample point, information is collected on nearly 200 attributes; some items are also collected for the entire segment. The sampling rates for the segments were variable, typically from 2 to 6 percent in agricultural strata and much lower in remote nonagricultural areas. The 1997 NRI Foundation Sample contained about 300,000 sample segments and about 800,000 sample points.

NRCS made several significant changes to the NRI program over the past 10 years, including transitioning from a 5-year periodic survey to an annual survey. The NRI's annual design

is a *supplemented panel design.*[3] A *core panel* of 41,000 segments is sampled each year, and *rotation (supplemental) panels* of 31,000 segments each vary by inventory year and allow an inventory to focus on an emerging issue. The core panel and the various supplemental panels are unequal probability subsamples from the 1997 NRI Foundation Sample.

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample.[4] The sample is statistically representative of cultivated cropland and formerly cultivated land currently in long-term conserving cover.

Nationally, there were over 30,000 samples in the original sample draw. A completed farmer survey was required to include the sample point in the CEAP sample. Some farmers declined to participate in the survey, others could not be located during the time period scheduled for implementing the survey, and other sample points were excluded for administrative reasons such as overlap with other USDA surveys. Some sample points were excluded because the surveys were incomplete or contained inconsistent information, land use found at the sample point had recently changed and was no longer cultivated cropland, or the crops grown were uncommon and model parameters for crop growth were not available. The NRI-CEAP usable sample consists of about 18,700 NRI points representing cropped acres, and about 13,000 NRI points representing land enrolled in the General Signup of the CRP.

The Ohio-Tennessee River Basin portion of the NRI-CEAP sample consists of 2,124 sample points representing 25.0 million cropped acres and 559 sample points representing 776,400 acres of cultivated cropland in long-term conserving cover. Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with the statistical sample. Margins of error for estimated cropped acres used in this report are provided in appendix A.

For example, the 95-percent confidence interval for the estimate of 25,038,900 cropped acres has a lower bound of 24,277,563 acres and an upper bound of 25,800,237 acres.

Table 5 provides a breakdown of sample sizes for cropped acres in the Ohio-Tennessee River Basin by cropping system and by subregion. Corn-soybean rotations (including corn-soybean rotations with close grown crops) comprise the dominant cropping systems in the region, representing 78 percent of cropped acres. About 95 percent of the cropped acres include corn or soybeans or both in the crop rotation.

[3] For more information on the NRI sample design, see www.nrcs.usda.gov/technical/NRI/.

[4] Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.

The CEAP sample was designed to allow reporting of results at the subregion (4-digit HUC) level in most cases. The acreage weights were derived so as to approximate total cropped acres by subregion as estimated by the full 2003 NRI. The sample size is too small, in most cases, for reliable and defensible reporting of results for areas below the subregion level. Sample sizes for some subregions were too small to reliably report cropped acres; estimates for these subregions were combined for reporting as shown in table 5.

The NRI-CEAP Cropland Survey

A farmer survey—the NRI-CEAP Cropland Survey—was conducted to obtain the additional information needed for modeling the 2,124 sample points with crops.[5] The USDA National Agricultural Statistics Service (NASS) administered the survey. Farmer participation was voluntary, and the information gathered is confidential. The survey content was specifically designed to provide information on farming activities for use with a physical process model to estimate field-level effects of conservation practices.

The survey obtained information on—

- crops grown for the previous 3 years, including double crops and cover crops;
- field characteristics, such as proximity to a water body or wetland and presence of tile or surface drainage systems;
- conservation practices associated with the field;
- crop rotation plan;
- application of commercial fertilizers (rate, timing, method, and form) for crops grown the previous 3 years;
- application of manure (source and type, consistency, application rate, method, and timing) on the field over the previous 3 years;
- application of pesticides (chemical, rate, timing, and method) for the previous 3 years;
- pest management practices;
- irrigation practices (system type, amount, and frequency);
- timing and equipment used for all field operations (tillage, planting, cultivation, harvesting) over the previous 3 years, and;
- general characteristics of the operator and the operation.

In a separate data collection effort, NRCS field offices provided information on the practices specified in conservation plans for the CEAP sample points.

Because of the large size of the sample, it was necessary to spread the data collection process over a 4-year period, from 2003 through 2006. In each year, surveys were obtained for a separate set of sample points. The final CEAP sample was constructed by pooling the set of usable, completed surveys from all 4 years.

[5] The surveys, the enumerator instructions, and other documentation can be found at www.nrcs.usda.gov/technical/nri/ceap.

Table 5. Estimated cropped acres based on the NRI-CEAP sample in the Ohio-Tennessee River Basin

Breakdown	Number of CEAP samples	Estimated acres	Percent of cropped acres
By Cropping System			
Corn-soybean only	1,401	17,174,590	69
Corn-soybean with close grown crops	209	2,372,131	9
Corn only	120	1,329,155	5
Soybean only	131	1,307,786	5
Soybean-wheat only	42	479,505	2
Corn and close grown crops	38	410,258	2
Hay-crop mix (most rotations include corn or soybean)	89	1,030,933	4
Remaining mix of crops	94	934,543	4
Total	2,124	25,038,900	100
By Subregion			
Ohio River Basin			
Allegheny and Monongahela River Basins (subregion codes 0501 and 502)	56	504,600	2
Upper Ohio-Beaver-Little Kanawha (subregion code 0503)	63	534,300	2
Muskingum River Basin (subregion code 0504)	85	1,018,300	4
Kanawha, Scioto, and Guyandotte-Big Sandy River Basins (subregion codes 0505, 0506, and 0507)	128	1,994,300	8
Great Miami Basin (subregion code 0508)	175	1,851,200	7
Middle Ohio-Raccoon-Little-Miami (subregion code 0509)	137	984,200	4
Licking-Kentucky and Green River Basin (subregion codes 0510 and 0511)	153	1,290,300	5
Wabash-Patoka-White River Basin (subregion code 0512)	853	12,943,300	52
Upper and Lower Cumberland River Basin (subregion code 0513)	90	813,600	3
Lower Ohio-Salt River Basin (subregion code 0514)	249	1,789,200	7
Tennessee River Basin			
Upper and Middle Tennessee (subregion codes 0601, 0602, and 0603)	78	938,000	4
Lower Tennessee-Duck River (subregion code 0604)	57	377,600	2
Total	2,124	25,038,900	100

Note: Estimates are from the 2003 NRI and the NRI-CEAP Cropland Survey. Cultivated cropland acres in this table differ slightly from estimates presented in tables 1 and 4 because of differences in data sources and estimation procedures.

Simulating the Effects of Weather

Weather is the predominant factor determining the loss of soil, nitrogen, phosphorus, and pesticides from farm fields, as well as the effects of conservation practices. To capture the effects of weather, each scenario was simulated using 47 years of actual daily weather data for the time period 1960 through 2006. The 47-year record is the extent of a serially complete daily data set of weather station data from weather station records available from the NCDC (National Climatic Data Center), for the period 1960 to 2006, including precipitation, temperature maximum, and temperature minimum (Eischeid et al. 2000). These data were combined with the respective PRISM (Parameter–Elevation Regressions on Independent Slopes Model; Daly et al. 1994) monthly map estimates to construct daily estimates of precipitation and temperature (Di Luzio et al. 2008). The same 47-year weather data were used in the HUMUS/SWAT simulations and in the APEX model simulations.

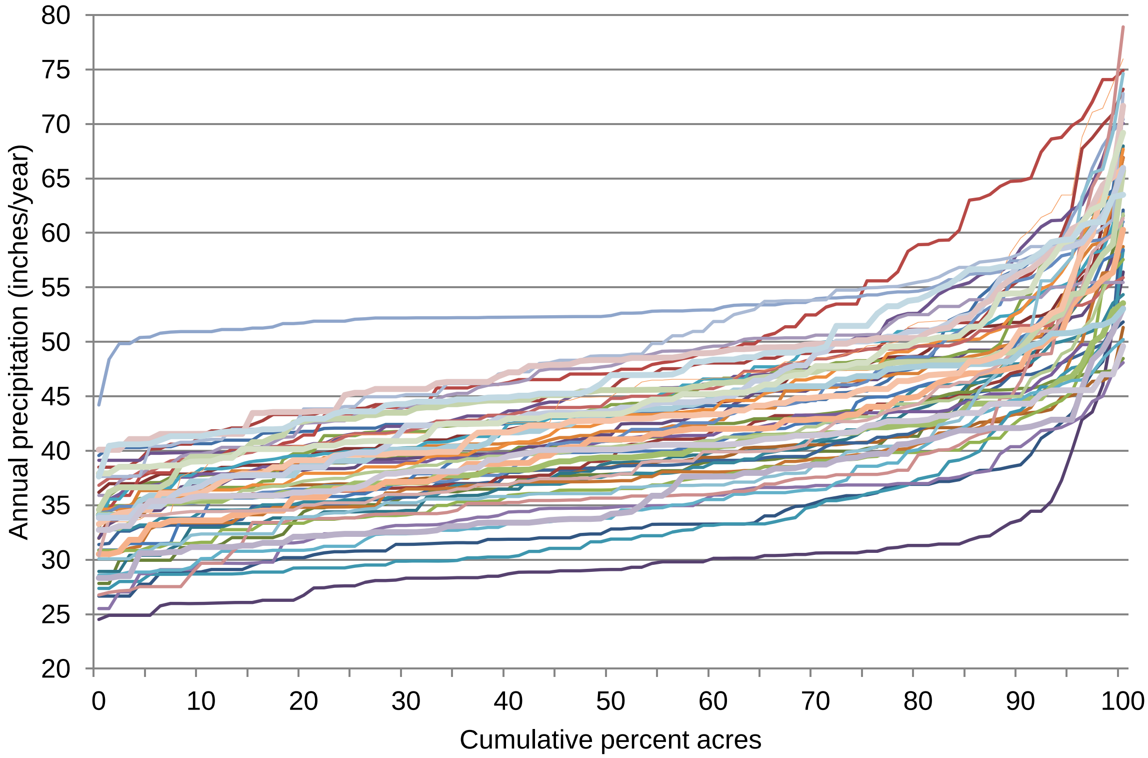
Annual precipitation over the 47-year simulation averaged about 42 inches for cropped acres in this region. However, annual precipitation varied substantially in the model simulations, both within the region and from year to year, as shown in figures 5 and 6.

Each curve in figure 5 shows how annual precipitation varied over the region in one of the 47 years. The family of curves shows the variability from year to year. The top curve shown is for the year 1990, the wettest year in this region during the 47 years. The curve for 1990 shows that precipitation exceeded 50 inches for all but 3 percent of cropped acres in the Ohio-Tennessee River Basin.

Year-to-year variability is especially pronounced—the average annual precipitation amount (representing all cropped acres) ranged from 30 inches in 1963 to 54 inches in 1990 over the 47 years (fig. 6).

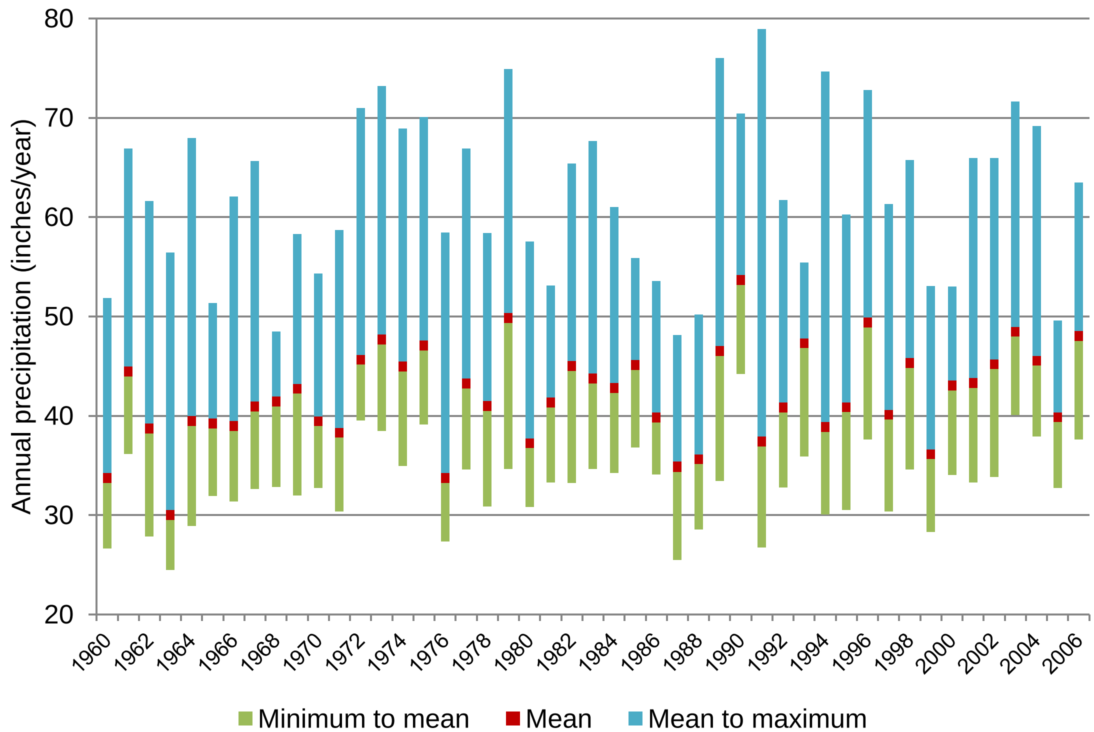
Throughout most of this report model results are presented in terms of the 47-year averages where weather is the only input variable that changes year to year. Since we used the cropping patterns and practices for the 2003–06 period, we did not simulate *actual* loses for each of these years. Rather, we provide estimates of what model outputs would *average* over the long term if weather varied as it has over the past 47 years. Similarly, estimates of the average effects of conservation practices include effectiveness in extreme weather years, such as floods and prolonged droughts, as represented in the 47-year weather record.

Figure 5. Cumulative distributions of annual precipitation used in the model simulations for cropped acres in the Ohio-Tennessee River Basin



Note:. Each of the 47 curves shown above represents a single year of data and shows how annual precipitation varies over the region in that year, starting with the acres with the lowest precipitation within the region and increasing to the acres with the highest precipitation. The family of curves shows how annual precipitation varies from year to year. Annual precipitation over the 47-year simulation averaged about 42 inches for cropped acres.

Figure 6. Mean, minimum, and maximum levels of annual precipitation used in the model simulations for cropped acres in the Ohio-Tennessee River Basin



Chapter 3
Evaluation of Conservation Practice Use—the Baseline Conservation Condition

This study assesses the use and effectiveness of conservation practices in the Ohio-Tennessee River Basin for the period 2003 to 2006 to determine the baseline conservation condition for the region. The baseline conservation condition provides a benchmark for estimating the effects of existing conservation practices as well as projecting the likely effects of alternative conservation treatment. Conservation practices that were evaluated include structural practices, annual practices, and long-term conserving cover.

Structural conservation practices, once implemented, are usually kept in place for several years. Designed primarily for erosion control, they also mitigate edge-of-field nutrient and pesticide loss. Structural practices evaluated include—

- in-field practices for water erosion control, divided into two groups:
  - practices that control overland flow (terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping), and
  - practices that control concentrated flow (grassed waterways, grade stabilization structures, diversions, and other structures for water control);
- edge-of-field practices for buffering and filtering surface runoff before it leaves the field (riparian forest buffers, riparian herbaceous cover, filter strips, field borders); and
- wind erosion control practices (windbreaks/shelterbelts, cross wind trap strips, herbaceous wind barriers, hedgerow planting).

*Annual conservation practic*es are management practices conducted as part of the crop production system each year. These practices are designed primarily to promote soil quality, reduce in-field erosion, and reduce the availability of sediment, nutrients, and pesticides for transport by wind or water. They include—

- residue and tillage management;
- nutrient management practices;
- pesticide management practices; and
- cover crops.

Long-term conservation cover establishment consists of planting suitable native or domestic grasses, forbs, or trees on environmentally sensitive cultivated cropland.

Historical Context for Conservation Practice Use

The use of conservation practices in the Ohio-Tennessee River Basin closely reflects the history of Federal conservation programs and technical assistance. In the beginning the focus was almost entirely on reducing soil erosion and preserving the soil's productive capacity. In the 1930s and 1940s, Hugh Hammond Bennett, the founder and first chief of the Soil Conservation Service (now Natural Resources Conservation Service) instilled in the national ethic the need to treat every acre to its potential by controlling soil erosion and water runoff. Land shaping structural practices (such as terraces, contour farming, and stripcropping) and sediment control structures were widely adopted. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. Conservation tillage, along with use of crop rotations and cover crops, was used either alone or in combination with structural practices. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres, tying farm commodity payments to conservation treatment of highly erodible land. The Conservation Reserve Program was established to enroll the most erodible cropland acres in multi-year contracts to plant acres in long-term conserving cover.

During the 1990s, the focus of conservation efforts began to shift from soil conservation and sustainability to reducing pollution impacts associated with agricultural production. Prominent among new concerns were the environmental effects of nutrient export from farm fields. Traditional conservation practices used to control surface water runoff and erosion control were mitigating a significant portion of these nutrient losses. Additional gains were being achieved using nutrient management practices—application of nutrients (appropriate timing, rate, method, and form) to minimize losses to the environment and maximize the availability of nutrients for crop growth.

Summary of Practice Use

Given the long history of conservation in the Ohio-Tennessee River Basin, it is not surprising to find that nearly all cropped acres in the region have evidence of some kind of conservation practice, especially erosion control practices. The conservation practice information collected during the study was used to assess the extent of conservation practice use. Key findings are the following.

- Structural practices for controlling water erosion are in use on 40 percent of cropped acres. On the 27 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 59 percent of those acres.
- Reduced tillage is common in the region; 93 percent of the cropped acres meet criteria for either no-till (52 percent) or mulch till (41 percent). All but 4 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- Two thirds of cropped acres are gaining soil organic carbon.
- Producers use either residue and tillage management practices or structural practices, or both, on 98 percent of the acres.
- While most acres have evidence of some nitrogen or phosphorus management, the majority of the acres in the

region lack consistent use of appropriate rates, timing, *and* method of application on each crop in every year of production, including nearly all of the acres receiving manure.
    - Appropriate timing of nitrogen applications is in use on about 64 percent of the acres for all crops in the rotation.
    - About 39 percent of cropped acres meet criteria for appropriate nitrogen application rates for all crops in the rotation.
    - Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production, however, are in use on only about 17 percent of cropped acres.
    - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 21 percent of the acres on all crops during every year of production.
    - Only about 10 percent of cropped acres meet full nutrient management criteria for *both* phosphorus and nitrogen management, including acres not receiving nutrient applications.
- During the 2003–06 period of data collection cover crops were used on about 2 percent of the acres in the region.
- An Integrated Pest Management (IPM) indicator showed that only about 5 percent of the acres were being managed at a relatively high level of IPM.
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of about 776,400 acres in the region, of which 70 percent is highly erodible land.

Structural Conservation Practices

Data on structural practices for the farm field associated with each sample point were obtained from four sources:

1. **The NRI-CEAP Cropland Survey** included questions about the presence of 12 types of structural practices: terraces, grassed waterways, vegetative buffers (in-field), hedgerow plantings, riparian forest buffers, riparian herbaceous buffers, windbreaks or herbaceous wind barriers, contour buffers (in-field), field borders, filter strips, critical area planting, and grade stabilization structures.
2. For fields with conservation plans, **NRCS field offices** provided data on all structural practices included in the plans.
3. **The USDA-Farm Service Agency** (FSA) provided practice information for fields that were enrolled in the Continuous CRP for these structural practices: contour grass strips, filter strips, grassed waterways, riparian buffers (trees), and field windbreaks (Alex Barbarika, USDA/FSA, personal communication).
4. **The 2003 NRI** provided additional information for practices that could be reliably identified from aerial photography as part of the NRI data collection process. These practices include contour buffer strips, contour farming, contour stripcropping, field stripcropping, terraces, cross wind stripcropping, cross wind trap strips, diversions, field borders, filter strips, grassed waterways or outlets, hedgerow planting, herbaceous wind barriers, riparian forest buffers, and windbreak or shelterbelt establishment.

Overland flow control practices are designed to slow the movement of water across the soil surface to reduce surface water runoff and sheet and rill erosion. NRCS practice standards for overland flow control include terraces, contour farming, stripcropping, in-field vegetative barriers, and field borders. These practices are found on about 15 percent of the cropped acres in the region; including 28 percent of the highly erodible land (table 6).

Concentrated flow control practices are designed to prevent the development of gullies along flow paths within the field. NRCS practice standards for concentrated flow control practices include grassed waterways, grade stabilization structures, diversions, and water and sediment control basins. About 26 percent of the cropped acres have one or more of these practices, including 42 percent of the highly erodible land (table 6).

Edge-of-field buffering and filtering practices, consisting of grasses, shrubs, and/or trees, are designed to capture the surface runoff losses that were not avoided or mitigated by the in-field practices. NRCS practice standards for edge-of-field mitigation practices include edge-of-field filter strips, riparian herbaceous buffers, and riparian forest buffers. CRP's buffer practices are included in this category. Edge-of-field buffering and filtering practices are in use on about 10 percent of all cropped acres in the region (table 6).

Overall, about 40 percent of the cropped acres in the Ohio-Tennessee River Basin are treated with one or more water erosion control structural practices (table 6). The treated percentage for highly erodible land acres is higher—59 percent.

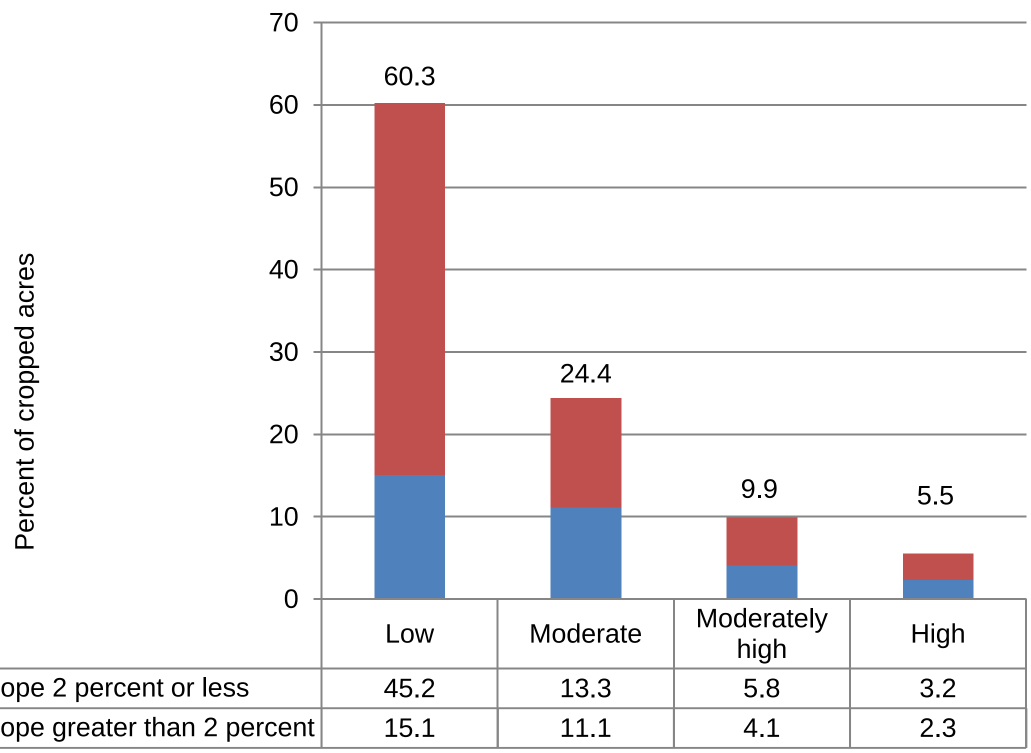
At each sample point, structural conservation practices for water erosion control were classified as either a high, moderately high, moderate, or low level of treatment according to criteria presented in figure 7. About 5 percent of cropped acres in the region have a high level of treatment (combination of edge-of-field buffering or filtering and at least one in-field structural practice). About 60 percent of the acres do not have structural practices for water erosion control; however, three-fourths of these acres have slopes less than 2 percent, some of which may not need to be treated with structural practices. (These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated for water erosion control in chapter 5.)

Table 6. Structural conservation practices in use for the baseline conservation condition, Ohio-Tennessee River Basin

Structural practice category	Conservation practice in use	Percent of non-HEL	Percent of HEL	Percent of cropped acres
Overland flow control practices	Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers	11	28	15
Concentrated flow control practices	Grassed waterways, grade stabilization structures, diversions, other structures for water control	20	42	26
Edge-of-field buffering and filtering practices	Riparian forest buffers, riparian herbaceous buffers, filter strips	10	10	10
One or more water erosion control practices	Overland flow, concentrated flow, or edge-of-field practice	33	59	40
Wind erosion control practices	Windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, hedgerow planting	2	2	2

Note: About 27 percent of cropped acres in the Ohio-Tennessee River Basin are highly erodible land (HEL). Soils are classified as HEL if they have an erodibility index (EI) score of 8 or higher. A numerical expression of the potential of a soil to erode, EI considers the physical and chemical properties of the soil and climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped.

Figure 7. Percent of cropped acres at four conservation treatment levels for structural practices, baseline conservation condition, Ohio-Tennessee River Basin



Criteria for four levels of treatment with structural conservation practices are:

- **High treatment**: Edge-of-field mitigation *and* at least one in-field structural practice (concentrated flow or overland flow practice) required.
- **Moderately high treatment**: Either edge-of-field mitigation required or both concentrated flow and overland flow practices required.
- **Moderate treatment**: No edge-of-field mitigation, either concentrated flow or overland flow practices required.
- **Low treatment**: No edge-of-field or in-field structural practices.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.

Wind erosion control practices are designed to reduce the force of the wind on the field. NRCS structural practices for wind erosion control include cross wind ridges, cross wind trap strips, herbaceous wind barriers, and windbreak/shelterbelt establishment. Wind erosion is not a significant resource concern for this region. Only 2 percent of the cropped acres in the region are treated for wind erosion using structural practices (table 6).

Residue and Tillage Management Practices

Simulations of the use of residue and tillage management practices were based on the field operations and machinery types reported in the NRI-CEAP Cropland Survey for each sample point. The survey obtained information on the timing, type, and frequency of each tillage implement used during the previous 3 years, including the crop to which the tillage operation applied. Model outcomes affected by tillage practices, such as erosion and runoff, were determined based on APEX processes of the daily tillage activities as reported in the survey.

To evaluate the level of residue and tillage management, the Soil Tillage Intensity Rating (STIR) (USDA-NRCS 2007) was used. STIR values represent the soil disturbance intensity, which was estimated for each crop at each sample point.[6] The soil disturbance intensity is a function of the kinds of tillage, the frequency of tillage, and the depth of tillage. STIR values were calculated for each crop and for each of the 3 years covered by the NRI-CEAP Cropland Survey (accounting for multiple crops or cover crops). By combining the STIR values for each crop year with model output on the long-term trend in soil organic carbon gain or loss, eight categories of residue and tillage management were identified, as defined in table 7.[7]

Overall, 93 percent of cropped acres in the Ohio-Tennessee River Basin meet the tillage intensity rating for either no-till or mulch till (table 7). About 52 percent meet the criteria for no-till—35 percent of cropped acres with gains in soil organic carbon and 17 percent with soil organic carbon loss. About 41 percent meet the tillage intensity criteria for mulch till—28 percent of cropped acres with gains in soil organic carbon and 14 percent with soil organic carbon loss. Only 4 percent of the acres are conventionally tilled for all crops in the rotation.

Most of the cropped acres (98 percent) in the Ohio-Tennessee River Basin have some kind of water erosion control practice—either reduced tillage or structural practices or both (table 8). About 36 percent meet tillage intensity for no-till or mulch till *and* have structural practices, including 53 percent of highly erodible land. About 57 percent of cropped acres meet tillage criteria without structural practices in use. Only 2 percent have no water erosion control practices.

Four levels of treatment for residue and tillage management practices were derived according to criteria presented in figure 8. (These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated for water erosion control in chapter 5.) The high and moderately high treatment levels represent the 63 percent of cropped acres that meet tillage intensity criteria for either no-till or mulch till with gains in soil organic carbon. The high treatment level (59 percent of the acres) includes only those acres where the tillage intensity criteria are met for *each* crop in the rotation. About 35 percent of cropped acres have a moderate level of treatment because some crops have reduced tillage but do not meet criteria for no-till or mulch till or they are gaining soil organic carbon but tillage intensity exceeds criteria for mulch till. Only 2.3 percent of the acres have a low treatment level, consisting of continuous conventional tillage for all crops in the rotation and loss of soil organic carbon.

[6] Percent residue cover was not used to evaluate no-till or mulch till because this criterion is not included in the current NRCS practice standard for Residue and Tillage Management. Residue is, however, factored into erosion and runoff estimates in APEX.

[7] STIR values in combination with carbon trends are in line with the use of the Soil Conditioning Index (SCI), which approximates the primary criteria for NRCS residue management standards. The NRCS practice standard, as applied at the field, may include other considerations to meet site specific resource concerns that are not considered in this evaluation.

Table 7. Residue and tillage management practices for the baseline conservation condition based on STIR ratings for tillage intensity and model output on carbon gain or loss, Ohio-Tennessee River Basin

Residue and tillage management practice in use		Percent of non-HEL	Percent of HEL	Percent of all acres
All acres				
Average annual tillage intensity for crop rotation meets criteria for no-till*		48	63	52
Average annual tillage intensity for crop rotation meets criteria for mulch till**		46	29	41
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till		3	3	3
Continuous conventional tillage in every year of crop rotation***		4	5	4
	Total	100	100	100
Acres with carbon gain				
Average annual tillage intensity for crop rotation meets criteria for no-till*		37	30	35
Average annual tillage intensity for crop rotation meets criteria for mulch till**		33	13	28
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till		2	1	2
Continuous conventional tillage in every year of crop rotation***		2	1	2
	Total	74	44	66
Acres with carbon loss				
Average annual tillage intensity for crop rotation meets criteria for no-till*		11	33	17
Average annual tillage intensity for crop rotation meets criteria for mulch till**		13	17	14
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till		1	3	1
Continuous conventional tillage in every year of crop rotation***		2	4	2
	Total	26	56	34

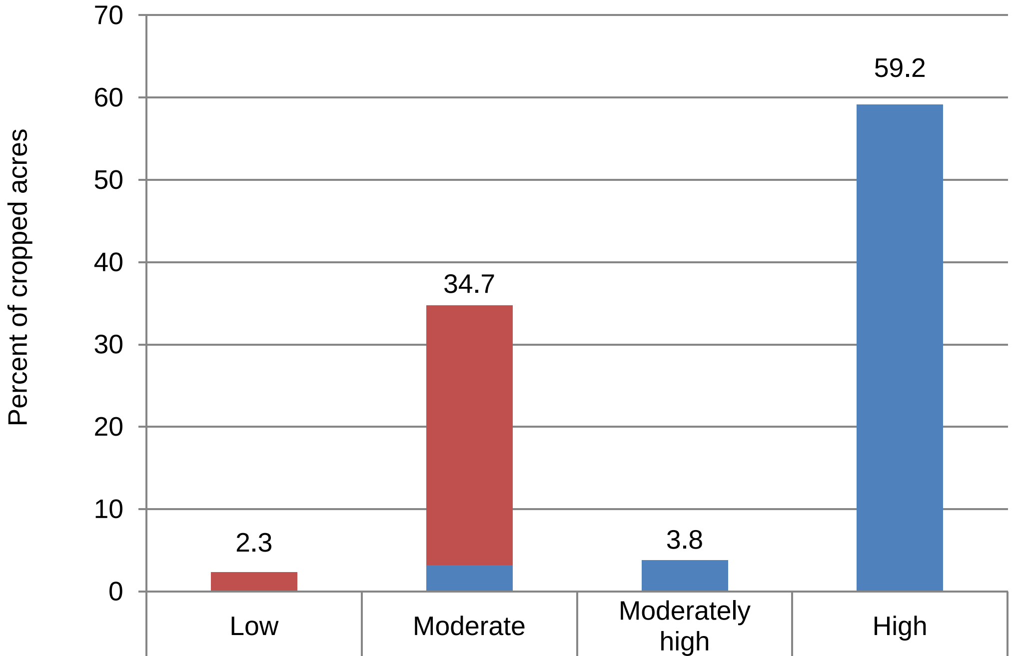
* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is less than 30.
** Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is between 30 and 100.
*** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is more than 100.
Note: A description of the Soil Tillage Intensity Rating (STIR) can be found at http://stir.nrcs.usda.gov/.
Note: HEL = highly erodible land. About 27 percent of cropped acres in the Ohio-Tennessee River Basin are highly erodible land (HEL).
Note: Percents may not add to totals because of rounding.
Note: Percent residue cover was not used to determine no-till or mulch till.

Table 8. Percent of cropped acres with water erosion control practices for the baseline conservation condition, Ohio-Tennessee River Basin

Conservation treatment	Percent of non-HEL	Percent of HEL	Percent of all cropped acres
No-till or mulch till with carbon gain, no structural practices	48	17	40
No-till or mulch till with carbon loss, no structural practices	16	21	17
Some crops with reduced tillage, no structural practices	2	1	2
Structural practices and no-till or mulch till with carbon gain	23	25	23
Structural practices and no-till or mulch till with carbon loss	8	28	13
Structural practices and some crops with reduced tillage	1	2	1
Structural practices only	1	4	2
No water erosion control treatment	2	1	2
All acres	100	100	100

Note: Percents may not add to totals because of rounding.

Figure 8. Percent of cropped acres at four conservation treatment levels for residue and tillage management, baseline conservation condition, Ohio-Tennessee River Basin



	Low	Moderate	Moderately high	High
Losing carbon	2.3	31.5	0.0	0.0
Gaining carbon	0.0	3.2	3.8	59.2

Criteria for four levels of treatment with residue and tillage management are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and crop rotation is gaining soil organic carbon.
- **Moderately high treatment**: *Average annual* tillage intensity meets criteria for mulch till or no-till and crop rotation is gaining soil organic carbon; some crops in rotation exceed tillage intensity criteria for mulch till.
- **Moderate treatment**: Some crops have reduced tillage but tillage intensity exceeds criteria for mulch till or crop rotation is gaining soil organic carbon and tillage intensity exceeds criteria for mulch till; most acres in this treatment level are losing soil organic carbon.
- **Low treatment**: Continuous conventional tillage and crop rotation is losing soil organic carbon.
- Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.

The evaluation of conservation practices and associated estimates of conservation treatment needs are based on practice use derived from a farmer survey conducted during the years 2003–06. Since that time, however, States in the Ohio-Tennessee River Basin have continued to work with farmers to enhance conservation practice adoption in an ongoing effort to reduce nonpoint source pollution contributing to water quality concerns. As a result, some practices may be in wider use within the watershed than the CEAP survey shows for 2003–06.

Conservation Crop Rotation

In the Ohio-Tennessee River Basin, crop rotations that meet NRCS criteria (NRCS practice code 328) occur on about 87 percent of the cropped acres. This practice consists of growing different crops in a planned rotation to manage nutrient and pesticide inputs, enhance soil quality, or reduce soil erosion. Including hay or a close grown crop in the rotation can have a pronounced effect on long-term average field losses of sediment and nutrients, as well as enhancement of soil quality.

The model outputs reported in chapter 4 reflect the effects of conservation crop rotations. However, the benefits of conservation crop rotation practices could not be assessed quantitatively in this study for two reasons. First, it was not possible to differentiate conservation crop rotations from crop rotations for other purposes, such as the control of pests or in response to changing markets. Second, the "no-practice scenario" would require simulation of mono-cropping systems. Not only was there inadequate information on chemical use and other farming practices for widespread mono-crop production, but arbitrary decisions about which crops to simulate at each sample point would be required to preserve the level of regional production.

Cover Crops

Cover crops are planted when the principal crops are not growing. The two most important functions of cover crops are (1) to provide soil surface cover and reduce soil erosion, and (2) to utilize and convert excess nutrients remaining in the soil from the preceding crop into plant biomass, thereby reducing nutrient leaching and minimizing the amount of soluble nutrients in runoff during the non-crop growing season. Cover crops also contribute to soil quality by capturing atmospheric carbon in plant tissue and adding it to the soil carbon.

The presence or absence of cover crops was determined from farmer responses in the NRI-CEAP Cropland Survey. The following criteria were used to identify a cover crop.

- A cover crop must be a close-grown crop that is not harvested as a principal crop, or if it is harvested, must have been specifically identified in the NRI-CEAP Cropland Survey as a cover crop as an indicator that the harvest was for an acceptable purpose (such as biomass removal or use as mulch or forage material).
- Spring-planted cover crops are inter-seeded into a growing crop or are followed by the seeding of a summer or late fall crop that may be harvested during that same year or early the next year.
- Late-summer-planted cover crops are followed by the harvest of another crop in the same crop year or the next spring.
- Fall-planted cover crops are followed by the spring planting of a crop for harvest the next year.

Some cover crops are planted for soil protection during establishment of spring crops such as sugar beets and potatoes. Early spring vegetation protects young crop seedlings.

In the Ohio-Tennessee River Basin, cover crops were not commonly used as a conservation practice during the period covered by the farmer survey (2003–06). Only about 2 percent of the acres (37 sample points) met the above criteria for a cover crop.

Irrigation Management Practices

Irrigation in the United States has its roots in the arid West where precipitation is insufficient to meet the needs of growing crops. In other parts of the United States, rainfall totals are sufficient in most years to produce satisfactory yields. The distribution of the rainfall during the crop growing season, however, is sometimes problematic, especially in years when precipitation is below average. In the Ohio-Tennessee River Basin, irrigation applications are sometimes used to supplement natural rainfall. This supplemental irrigation water can overcome soil moisture deficiencies during drought stress periods and improve yields.

Irrigation applications are made with either a pressure or a gravity system. Gravity systems, as the name implies, utilizes gravitational energy to move water from higher elevations to lower elevations, such as moving water from a ditch at the head of a field, across the field to the lower end. Pumps are most often used to create the pressure in pressure systems, and the water is applied under pressure through pipes and nozzles of one form or another. There are also variations such as where water is diverted at higher elevations and the pressure head created by gravity is substituted for the energy of a pump.

Proper irrigation involves applying appropriate amounts of water to the soil profile to reduce any plant stress while at the same time minimizing water losses through evaporation, deep percolation, and runoff. Conversion of much of the gravity irrigated area to pressure systems and the advent of pressure systems in rain-fed agricultural areas has reduced the volumes of irrigation water lost to deep percolation and end-of-field runoff, but has greatly increased the volume of water lost to evaporation in the pressurized sprinkling process. Modern sprinklers utilize improved nozzle technology to increase droplet size as well as reduce the travel time from the nozzle to the ground. Irrigation specialists consider the center pivot or linear move sprinkler with low pressure spray and low flow systems such as drip and trickle systems as the current state of the art.

Only about 1.3 percent of cropped acres—318,000 acres—receive irrigation water in the Ohio-Tennessee River Basin. Irrigation in the Ohio-Tennessee River Basin is exclusively by pressure systems. Most common pressure systems are center-pivot or linear-move systems with impact sprinkler heads (81 percent of irrigated acres) followed by center-pivot or linear-move systems with more efficient low-pressure spray or near-ground emitters (7 percent of irrigated acres). Traveling big gun sprinklers are used on 9 percent of irrigated acres. Approximately 10 percent of the irrigated acres have systems with efficiencies at or better than the current state of the art.

Nutrient Management Practices

Nitrogen and phosphorus are essential inputs to profitable crop production. Farmers apply these nutrients to the land as commercial fertilizers and manure to promote plant growth and increase crop yields. Not all of the nutrients applied to the land, however, are taken up by crops; some are lost to the environment, which can contribute to offsite water quality problems.

Sound nutrient management systems can minimize nutrient losses from the agricultural management zone while providing adequate soil fertility and nutrient availability to ensure realistic yields. (The agricultural management zone is defined as the zone surrounding a field that is bounded by the bottom of the root zone, edge of the field, and top of the crop canopy.) Such systems are tailored to address the specific cropping system, nutrient sources available, and site characteristics of each field. Nutrient management systems have four basic criteria for application of commercial fertilizers and manure.

1. Apply nutrients at the **appropriate rate** based on soil and plant tissue analyses and realistic yield goals.
2. Apply the **appropriate form** of fertilizer and organic material with compositions and characteristics that resist nutrient losses from the agricultural management zone.
3. Apply at the **appropriate time** to supply nutrients to the crop when the plants have the most active uptake and biomass production, and avoid times when adverse weather conditions can result in large losses of nutrients from the agricultural management zone.
4. Apply using the **appropriate application method** that provides nutrients to the plants for rapid, efficient uptake and reduces the exposure of nutrient material to forces of wind and water.

Depending on the field characteristics, these nutrient management techniques can be coupled with other conservation practices such as conservation crop rotations, cover crops, residue management practices, and structural practices to minimize the potential for nutrient losses from the agricultural management zone. Even though nutrient transport and losses from agricultural fields cannot be completely eliminated, they can be minimized by careful management and kept within an acceptable level.

The presence or absence of nutrient management practices was based on information on the timing, rate, and method of application for manure and commercial fertilizer as reported by the producer in the NRI-CEAP Cropland Survey. The appropriate form of nutrients applied was not evaluated because the survey was not sufficiently specific about the material formulations that were applied. The following criteria were used to identify the appropriate rate, time, and method of nutrient application for each crop or crop rotation.

- All commercial fertilizer and manure applications are within 3 weeks prior to plant date, at planting, or within 60 days after planting.
- The method of application for commercial fertilizer or manure is some form of incorporation or banding or spot treatment or foliar applied.
- The rate of nitrogen application, including the sum of both commercial fertilizer and manure nitrogen available for crops in the year of application, is—
    - less than 1.4 times the amount of nitrogen removed in the crop yield at harvest for *each* crop[8], except for cotton and small grain crops;
    - less than 1.6 times the amount of nitrogen removed in the crop yield at harvest for small grain crops (wheat, barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale);
    - less than 60 pounds of nitrogen per bale of cotton harvested.
- The rate of phosphorus application summed over all applications and crops in the rotation, including both commercial fertilizer and manure phosphorus, is less than 1.1 times the amount of phosphorus removed in the crop yields at harvest summed over all crops in the rotation.

Phosphorus application rate criteria apply to the *full crop rotation* to account for infrequent applications intended to provide phosphorus for multiple crops or crop years, which is often the case with manure applications. Nitrogen application rate criteria apply to *each* crop in the rotation.

These nutrient management criteria are intended to represent practice recommendations commonly found in comprehensive nutrient management conservation plans and generally are consistent with recommended rates. While consistent with NRCS standards, they do not necessarily represent the best possible set of nutrient management practices. For example, lower application rates are possible when timing and method criteria are also met and when soil erosion and runoff are controlled.

As shown in table 9, the majority of acres in the Ohio-Tennessee River Basin meet one or more of the criteria for nutrient management:

- 85 percent of cropped acres meet criteria for timing of nitrogen applications for one or more crops and 88 percent meet criteria for timing of phosphorus applications for one or more crops;
- 89 percent of cropped acres meet criteria for method of nitrogen application for one or more crops and 88 percent meet criteria for method of phosphorus application for one or more crops;
- 93 percent of cropped acres meet criteria for nitrogen application rate for one or more crops; and
- 3 percent of cropped acres have no nitrogen applied and less than 1 percent have no phosphorus applied.

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[8] The 1.4 ratio of application rate to yield represents 70-percent use efficiency for applied nitrogen, which has traditionally been accepted as good nitrogen management practice. The 30 percent "lost" includes plant biomass left in the field, volatilization during and following application, immobilization by soil and soil microbes, and surface runoff and leaching losses. A slightly higher ratio is used for small grain crops to maintain yields at current levels.

Table 9. Nutrient management practices for the baseline conservation condition, Ohio-Tennessee River Basin

	Percent of acres without manure applied	Percent of acres with manure applied	Percent of all cropped acres
Nitrogen*			
No N applied to any crop in rotation	4	0	3
For samples where N is applied:			
Time of application			
All crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	68	14	64
Some but not all crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	18	53	21
No crops in rotation have application of N (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	10	34	12
Method of application			
All crops in rotation have N applied with incorporation or banding/foliar/spot treatment	47	27	46
Some but not all crops in rotation have N applied with incorporation or banding/foliar/spot treatment	40	72	43
No crops in rotation have N applied with incorporation or banding/foliar/spot treatment	9	1	8
Rate of application			
All crops in rotation meet the nitrogen rate criteria described in text	39	35	39
Some but not all crops in rotation meet the nitrogen rate criteria described in text	53	58	54
No crops in rotation meet the nitrogen rate criteria described in text	4	7	4
Timing and method and rate of application			
All crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	18	3	17
Some but not all crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	65	65	65
No crops meet the nitrogen rate , timing criteria, and method criteria described above	13	32	14
Phosphorus*			
No P applied to any crop in rotation	0.4	0.0	0.4
For samples where P is applied:			
Time of application			
All crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	66	14	61
Some but not all crops have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	25	51	27
No crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	9	35	11
Method of application			
All crops in rotation have P applied with incorporation or banding/foliar/spot treatment	48	39	47
Some but not all crops in rotation have P applied with incorporation or banding/foliar/spot treatment	39	60	41
No crops in rotation have P applied with incorporation or banding/foliar/spot treatment	12	1	11
Rate of application			
Crop rotation has P applied at a rate less than 1.1 times the removal of P in the yield at harvest for the crop rotation	44	30	43
Crop rotation has P applied at a rate more than 1.1 times the removal of P in the yield at harvest for the crop rotation	56	70	57
Timing and method and rate of application			
Crop rotation has P rate less than 1.1 times removal at harvest and meet timing and method criteria described above	23	1	21
Crop rotation has P rate less than 1.1 times removal at harvest and some but not all crops meet timing and method criteria described above	18	25	19
Crop rotation has P rate more than 1.1 times removal at harvest and may or may not meet timing and method criteria described above	58	74	59
Nitrogen and Phosphorus			
Crop rotation P rate less than 1.1 and N rate criteria described in text and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	11	0	10
Crop rotation P rate less than 1.1 and N rate criteria appropriate for full conservation treatment (see text) and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	8	0	7
All sample points	100	100	100

Note: About 9 percent of cropped acres (2.1 million acres) have manure applied. Percents may not add to 100 because of rounding.

* These estimates include adjustments made to the reported data on nitrogen and phosphorus application rates from the survey because of missing data and data-entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques. Since crop growth, and thus canopy development which decreases erosion, is a function of nitrogen and phosphorus, it was necessary to add additional nitrogen and phosphorus when the reported levels were insufficient to support reasonable crop yields throughout the 47 years in the model simulation. The approach taken was to first identify crop samples that have application rates recorded erroneously or were under-reported in the survey. The model was used to identify these samples by running the simulation at optimal levels of nitrogen and phosphorus for crop growth. The set of crop samples identified were treated as if they had missing data. Additional nitrogen or phosphorus was added to these crop samples so that the total nitrogen or phosphorus use was similar to that for the unadjusted set of crop samples. About 24 percent of the acres received a nitrogen adjustment for one or more crops. About 40 percent of the acres received a phosphorus adjustment for one or more crops. Nitrogen and phosphorus were added by increasing the existing applications (thus preserving the reported timing and methods), when present, or were applied at plant. (For additional information on adjustment of nutrient application rates, see “Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling,” available at http://www.nrcs.usda.gov/technical/nri/ceap

Fewer acres, however, meet criteria for all crops in the rotation:

- 64 percent of cropped acres meet criteria for timing of nitrogen applications on all crops and 61 percent of cropped acres meet criteria for timing of phosphorus applications on all crops.
- 46 percent of cropped acres meet criteria for method of nitrogen application on all crops and 47 percent meet criteria for method of phosphorus application on all crops.
- 39 percent of cropped acres meet criteria for nitrogen application rate on all crops and 43 percent meet criteria for phosphorus application rates for the full crop rotation.

Nutrients applied in the fall for a spring-planted crop are generally more susceptible to environmental losses than spring applications. Based on the survey, about 21 percent of the cropped acres in the Ohio-Tennessee River Basin received fall applications of either commercial nitrogen fertilizer or manure on at least one crop in the rotation. About 27 percent of cropped acres received fall applications of either commercial phosphorus fertilizer or manure on at least one crop in the rotation.

Acres with manure applied—about 9 percent of cropped acres in the region—generally meet the criteria for nutrient application less frequently than for acres receiving only commercial fertilizer:

- Only 14 percent of cropped acres receiving manure meet criteria for timing of nitrogen and phosphorus applications on all crops, compared to 68 percent (nitrogen) and 66 percent (phosphorus) for acres not receiving manure;
- 27 percent of cropped acres receiving manure meet criteria for nitrogen application method on all crops, compared to 47 percent for acres not receiving manure;
- 39 percent of cropped acres receiving manure meet criteria for phosphorus application method on all crops, compared to 48 percent for acres not receiving manure;
- 35 percent of cropped acres receiving manure meet criteria for nitrogen application rates, compared to 39 percent for acres not receiving manure; and
- 30 percent of cropped acres receiving manure meet criteria for phosphorus application rates, compared to 44 percent for acres not receiving manure.

The highest percentages of cropped acres with manure applied are in the northeast portion of the region: the Allegheny and Monongahela River subregions (44 percent), the Upper Ohio-Beaver-Little Kanawha River subregion (18 percent) and the Muskingum River subregion (30 percent) (Appendix B, table B1).

Only a few acres meet all nutrient management criteria, including very few of the acres receiving manure:

- 17 percent of the acres meet all criteria for nitrogen applications, including only 3 percent of the acres receiving manure;
- 21 percent of the acres meet all criteria for phosphorus applications, including only 1 percent of the acres receiving manure;
- Only 10 percent of cropped acres meet criteria for *both* phosphorus and nitrogen management (table 9), including acres not receiving nutrient applications.

Lower nitrogen rate criteria are appropriate for acres that meet application timing and method criteria and also are fully treated for soil erosion control because more of the nitrogen applied is retained on the field and is therefore available for crop growth. In the simulation of additional soil erosion control and nutrient management (full treatment) in chapter 6, the rates of nitrogen application, including both commercial fertilizer and manure nitrogen, were proportionately reduced to the following levels—

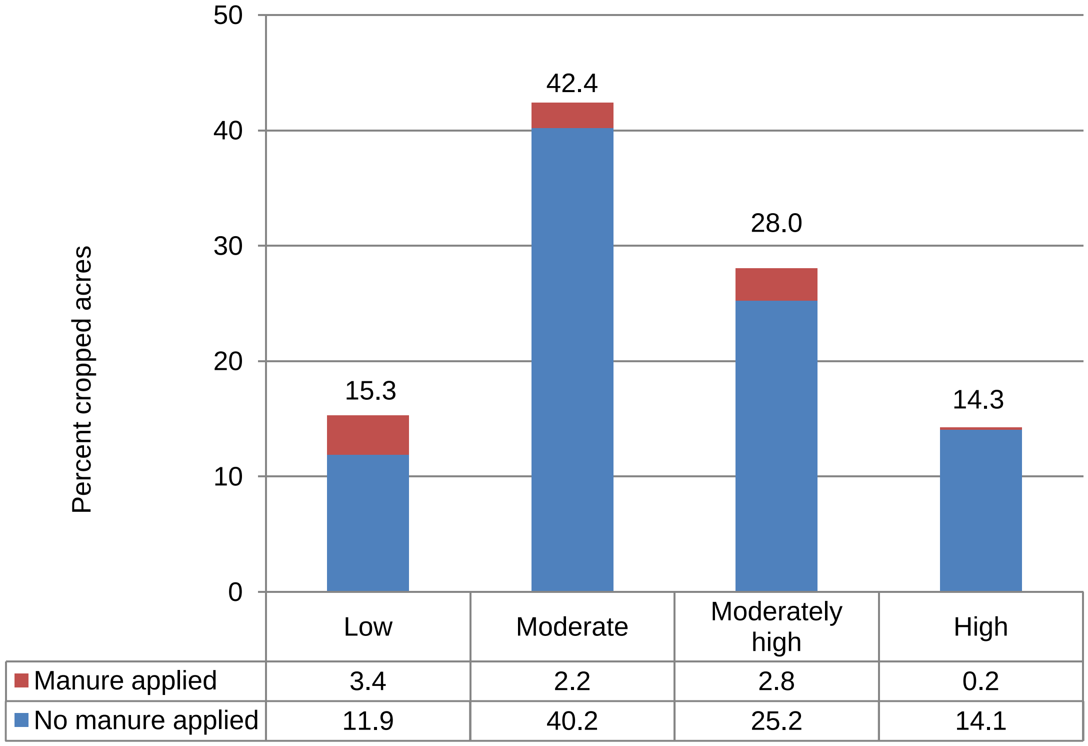
- 1.2 times the amount of nitrogen removed in the crop yield at harvest for *each* crop, except for cotton and small grain crops;
- 1.5 times the amount of nitrogen removed in the crop yield at harvest for small grain crops; and
- 50 pounds of nitrogen per bale of cotton harvested.

Only 7 percent of cropped acres in the region meet *all* nutrient management criteria including these lower nitrogen rate criteria and including acres not receiving nutrient applications (table 9).

Four levels of treatment for nitrogen and phosphorus management were derived for use in evaluating the adequacy of nutrient management. (These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated in chapter 5.) Criteria for the treatment levels are presented in figures 9 and 10. The high treatment level represents consistent use of appropriate rate, timing, and method for all crops, including the lower nitrogen application rate criteria appropriate for full conservation treatment conditions.

Based on these treatment levels, about 14 percent of the acres in the Ohio-Tennessee River Basin have a high level of nitrogen management and about 22 percent have a high level of phosphorus management (figs. 9 and 10). Few acres with manure applied meet the criteria for the high treatment levels. About 28 percent of cropped acres have a moderately high treatment level for nitrogen and about 22 percent have a moderately high treatment level for phosphorus. About 15 percent of cropped acres have a low level of nitrogen management and 44 percent of the acres have a low level of phosphorus management.

Figure 9. Percent of cropped acres at four conservation treatment levels for nitrogen management, baseline conservation condition, Ohio-Tennessee River Basin

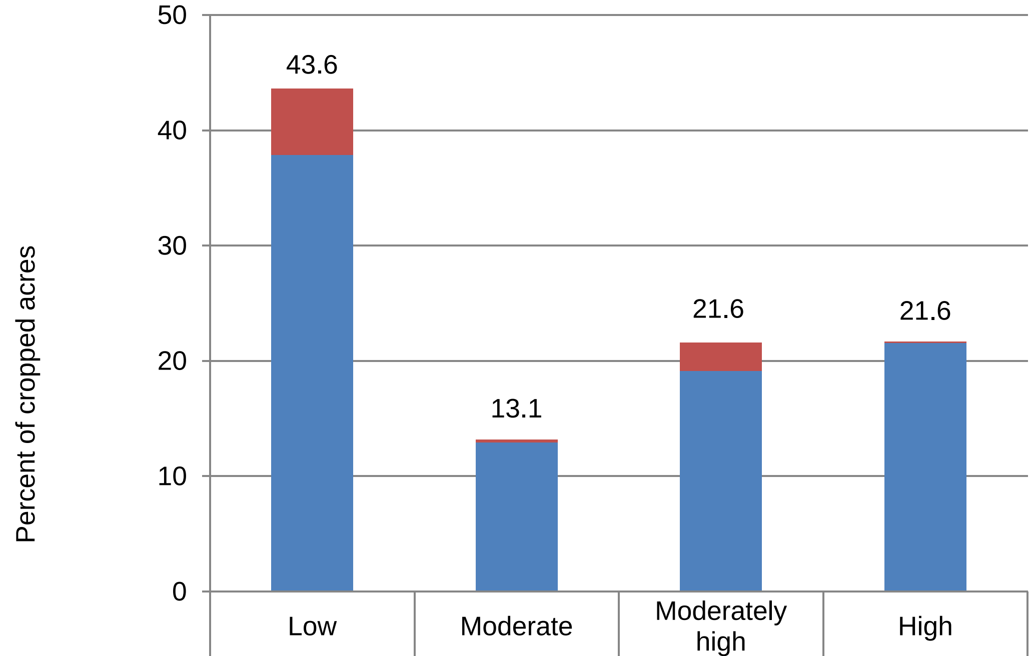


Criteria for four levels of nitrogen management are:

- **High treatment**: All crops have: (1) total nitrogen application rates (including manure) less than 1.2 times the nitrogen in the crop yield for crops other than cotton and small grains, less than 1.5 times the nitrogen in the crop yield for small grains, and less than 50 pounds of nitrogen applied per cotton bale; (2) all applications occur within 3 weeks before planting or within 60 days after planting; and (3) all applications are incorporated or banding/foliar/spot treatment is used.
- **Moderately high treatment**: All crops have total nitrogen application rates (including manure) less than 1.4 times the nitrogen in the crop yield for crops other than cotton and small grains, less than 1.6 times the nitrogen in the crop yield for small grains, and less than 60 pounds of nitrogen applied per cotton bale for all crops. Timing and method of application criteria may or may not be met.
- **Moderate treatment**: All crops meet either the above criteria for timing *or* method, but do not meet criteria for rate.
- **Low treatment**: Some or all crops in rotation exceed criteria for rate and either timing or method.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.

Figure 10. Percent of cropped acres at four conservation treatment levels for phosphorus management, baseline conservation condition, Ohio-Tennessee River Basin



	Low	Moderate	Moderately high	High
Manure applied	5.7	0.2	2.5	0.1
No manure applied	37.9	12.9	19.1	21.5

Criteria for four levels of phosphorus management are:

- **High treatment**: (1) total phosphorus application rates (including manure) summed over all crops are less than 1.1 times the phosphorus in the crop yields for the crop rotation, (2) all applications occur within 3 weeks before planting or within 60 days after planting, and (3) all applications are incorporated or banding/foliar/spot treatment was used. (Note that phosphorus applications for individual crops could exceed 1.1 times the phosphorus in the crop yield but total applications for the crop rotation could not.)
- **Moderately high treatment**: Total phosphorus application rates (including manure) are less than 1.1 times the phosphorus in the crop yield for the crop rotation. No method or timing of application criteria is applied.
- **Moderate treatment**: Sample points that do not meet the high or moderately high criteria but all phosphorus applications for all crops have appropriate time *and* method of application.
- **Low treatment**: All acres have excessive application rates over the crop rotation and inadequate method or timing of application for at least one crop in the rotation.
- Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.

Pesticide Management Practices

The presence or absence of pesticide management practices was based on an Integrated Pest Management (IPM) indicator developed using producer responses to the set of IPM-related questions in the NRI-CEAP Cropland Survey (table 10).[9]

Adoption of IPM systems can be described as occurring along a continuum from largely reliant on prophylactic control measures and pesticides to multiple-strategy, biologically intensive approaches. IPM adoption is not usually an either/or situation. The practice of IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environment scenario. Where appropriate, each site should have in place a management strategy for **Prevention, Avoidance, Monitoring,** and **Suppression** of pest populations (the **PAMS** approach) (Coble 1998). In order to qualify as IPM practitioners, growers would use tactics in all four PAMS components.

Prevention is the practice of keeping a pest population from infesting a field or site, and should be the first line of defense. It includes such tactics as using pest-free seeds and transplants, preventing weeds from reproducing, irrigation scheduling to avoid situations conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease organisms.

Avoidance may be practiced when pest populations exist in a field or site but the impact of the pest on the crop can be avoided through some cultural practice. Examples of avoidance tactics include crop rotation in which the crop of choice is not a host for the pest, choosing cultivars with genetic resistance to pests, using trap crops or pheromone traps, choosing cultivars with maturity dates that may allow harvest before pest populations develop, fertilization programs to promote rapid crop development, and simply not planting certain areas of fields where pest populations are likely to cause crop failure.

Monitoring and proper identification of pests through surveys or scouting programs, including trapping, weather monitoring and soil testing where appropriate, are performed as the basis for suppression activities. Records are kept of pest incidence and distribution for each field or site. Such records form the basis for crop rotation selection, economic thresholds, and suppressive actions.

Suppression of pest populations may be necessary to avoid economic loss if prevention and avoidance tactics are not successful. Suppressive tactics include *cultural* practices such as narrow row spacing or optimized in-row plant populations, alternative tillage approaches such as no-till or strip-till systems, cover crops or mulches, or using crops with allelopathic potential in the rotation. *Physical* suppression tactics include cultivation or mowing for weed control, baited or pheromone traps for certain insects, and temperature management or exclusion devices for insect and disease management. *Biological* controls, including mating disruption for insects, are alternatives to conventional pesticides, especially where long-term control of a troublesome pest species can be attained. Naturally occurring biological controls exist, where they exist, are important IPM tools. *Chemical pesticides* are applied as a last resort in suppression systems using a sound management approach, including selection of pesticides with low risk to non-target organisms.

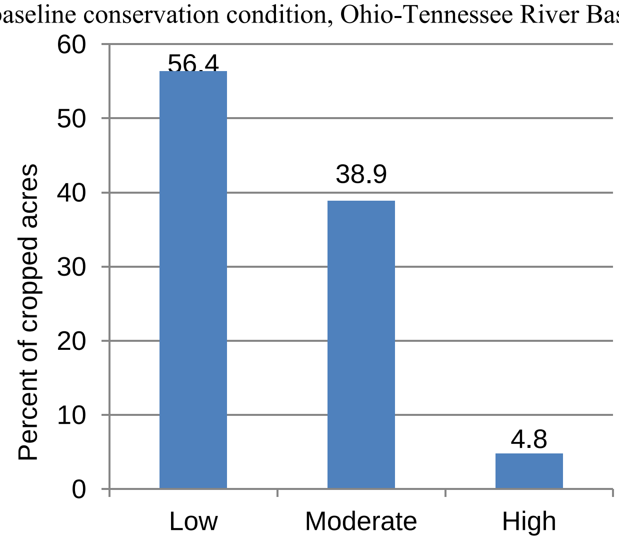
An IPM index was developed to determine the level of IPM activity for each sample point. The index was constructed as follows.

- Scores were assigned to each question by a group of IPM experts.
- Scores for each PAMS category were normalized to have a maximum score of 100.
- The four PAMS categories were also scored in terms of relative importance for an IPM index: prevention = 1/6, avoidance = 1/6, monitoring = 1/3, and suppression = 1/3.
- The IPM indicator was calculated by multiplying the normalized PAMS category by the category weight and summing over the categories.

An IPM indicator score greater than 60 defined sample points with a high level of IPM activity. Sample points with an IPM indicator score of 35 to 60 were classified as moderately high IPM treatment and sample points with an IPM score less than 35 were classified as low IPM treatment.

About 5 percent of the acres in the Ohio-Tennessee River Basin have a high level of IPM activity (fig. 11). About 39 percent have a moderate level of IPM activity, and 56 percent have a low level of IPM activity.

Figure 11. Integrated Pesticide Management indicator for the baseline conservation condition, Ohio-Tennessee River Basin



[9] For a full documentation of the derivation of the IPM indicator, see "Integrated Pest Management (IPM) Indicator Used in the CEAP Cropland Modeling," available at http://www.nrcs.usda.gov/technical/nri/ceap.

Table 10. Summary of survey responses to pest management questions, Ohio-Tennessee River Basin

Survey question	Number samples with "yes" response	Percent of cropped acres
Prevention		
Pesticides with different action rotated or tank mixed to prevent resistance	538	27
Plow down crop residues	273	14
Chop, spray, mow, plow, burn field edges, etc.	811	39
Clean field implements after use	579	27
Remove crop residue from field	109	5
Water management used to manage pests (irrigated samples only)	5	<1
Avoidance		
Rotate crops to manage pests	1,512	73
Use minimum till or no-till to manage pests	1,305	61
Choose crop variety that is resistant to pests	646	32
Planting locations selected to avoid pests	130	7
Plant/harvest dates adjusted to manage pests	124	6
Monitoring		
Scouting practice: general observations while performing routine tasks	1,086	50
Scouting practice: deliberate scouting	735	36
--Established scouting practice used	193	10
--Scouting due to pest development model	138	7
--Scouting due to pest advisory warning	138	8
Scouting done by: (only highest of the 4 scores is used)		
--Scouting by operator	579	30
--Scouting by employee	17	1
--Scouting by chemical dealer	76	3
--Scouting by crop consultant or commercial scout	77	3
Scouting records kept to track pests?	264	12
Scouting data compared to published thresholds?	339	18
Diagnostic lab identified pest?	97	4
Weather a factor in timing of pest management practice	652	31
Suppression		
Pesticides used?	2,090	98
Weather data used to guide pesticide application	1,136	55
Biological pesticides or products applied to manage pests	95	5
Pesticides with different mode of action rotated or tank mixed to prevent resistance	538	27
Pesticide application decision factor (one choice only):		
--Routine treatments or preventative scheduling	1,346	62
--Comparison of scouting data to published thresholds	89	4
--Comparison of scouting data to operator's thresholds	129	7
--Field mapping or GPS	7	1
--Dealer recommendations	286	14
--Crop consultant recommendations	55	3
--University extension recommendations	9	<1
--Neighbor recommendations	4	<1
--"Other"	56	3
Maintain ground covers, mulch, or other physical barriers	575	27
Adjust spacing, plant density, or row directions	355	16
Release beneficial organisms	10	1
Cultivate for weed control during the growing season	123	7
Number of respondents	2,124	100

Note: The scores shown in this table were used to develop an IPM indicator as discussed in the text.

Conservation Cover Establishment

Establishing long-term cover of grass, forbs, or trees on a site provides the maximum protection against soil erosion. Conservation cover establishment is often used on cropland with soils that are vulnerable to erosion or leaching. The practice is also effective for sites that are adjacent to waterways, ponds, and lakes. Because these covers do not require annual applications of fertilizer and pesticides, this long-term conserving cover practice greatly reduces the loss of nitrogen and phosphorus from the site, and nearly eliminates pesticide loss. Because conservation covers are not harvested, they generate organic material that decomposes and increases soil organic carbon. For this study, the effect of a long-term conserving cover practice was estimated using acres enrolled in the General Signup of the CRP. The CRP General Signup is a voluntary program in which producers with eligible land enter into 10- to 15-year contracts to establish long-term cover to reduce soil erosion, improve water quality, and enhance wildlife habitat.

Landowners receive annual rental payments and cost-share assistance for establishing and maintaining permanent vegetative cover. To be eligible for enrollment in the CRP General Signup, the field (or tract) must meet specified crop history criteria.

Other factors governing enrollment in the CRP include natural resource-based eligibility criteria, an Environmental Benefits Index (EBI) used to compare and rank enrollment offers, acreage limits, and upper limits on the proportion of a county's cropland that can be enrolled (USDA Farm Service Agency 2004; Wiebe and Gollehon 2006). Initially, the eligibility criteria included only soil erosion rates and inherent soil erodibility. During the 1990s and to date, the eligibility criteria have continued to evolve, with increasing emphasis placed on issues other than soil erodibility. For contract offer ranking, weight was given to proposals that also benefited wildlife, air and water quality, and other environmental concerns.

As of 2003, about 31.5 million acres were enrolled in the CRP General Signup nationally, including about 776,400 in the Ohio-Tennessee River Basin (USDA/NRCS 2007). Approximately 70 percent of the cropland acres enrolled in the CRP in the Ohio-Tennessee River Basin are classified as highly erodible land. The inclusion of non-highly erodible land is due to both the expansion of enrollment eligibility criteria beyond soil erosion issues and the fact that farmers were allowed to enroll entire fields in the CRP if a specified portion of the field (varied by signup and eligibility criterion) met the criteria.

In the Ohio-Tennessee River Basin, 78 percent of the CRP land is planted to introduced grasses, 12 percent to trees, 6 percent to native grasses, and 4 percent to wildlife habitat. The plantings designated in the NRI database for each sample point were simulated in the APEX model. However, in all cases the simulated cover was a mix of species and all points included at least one grass and one clover species.

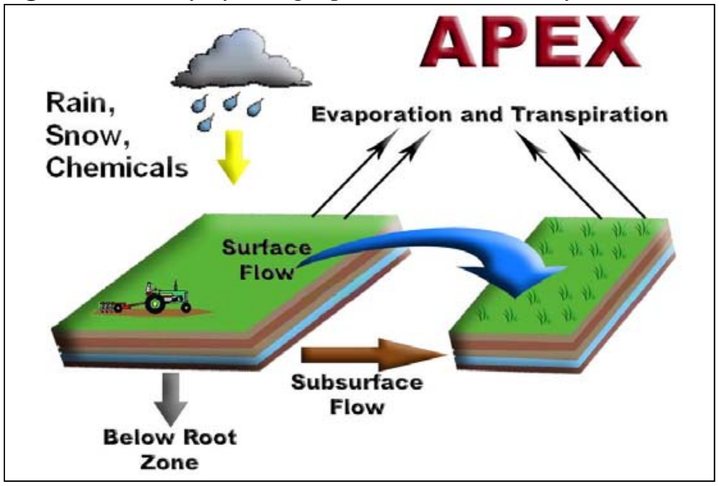
Chapter 4
Onsite (Field-Level) Effects of Conservation Practices

The Field-Level Cropland Model—APEX

A physical process model called APEX was used to simulate the effects of conservation practices at the field level (Williams et al. 2006; Williams et al. 2008; Gassman et al. 2009 and 2010).[10] The I_APEX model run management software developed at the Center for Agricultural and Rural Development, Iowa State University, was used to perform the simulations in batch mode.[11]

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides (fig. 12). The APEX model and its predecessor, EPIC (Environmental Policy Impact Calculator), have a long history of use in simulation of agricultural and environmental processes and of the effect of agricultural technology and government policy (Izaurralde et al. 2006;Williams 1990; Williams et al. 1984; Gassman et al. 2005).[12]

Figure 12. Daily hydrologic processes simulated by APEX



On a daily basis, APEX simulates the farming operations used to grow crops, such as planting, tillage before and after planting, application of nutrients and pesticides, application of manure, irrigation, and harvest. Weather events and their interaction with crop cover and soil properties are simulated; these events affect crop growth and the fate and transport of water and chemicals through the soil profile and over land to the edge of the field. Over time, the chemical makeup and physical structure of the soil may change, which in turn affect crop yields and environmental outcomes. Crop residue remaining on the field after harvest is transformed into organic matter. Organic matter may build up in the soil over time, or it may degrade, depending on climatic conditions, cropping systems, and management.

APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion, and the loss of sediment beyond the edge of the field. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field. Exchange of gaseous forms between the soil and the atmosphere is simulated, including losses of gaseous nitrogen compounds.

The NRI-CEAP Cropland Survey was the primary source of information on all farming activities simulated using APEX. Crop data were transformed for the model into a crop rotation for each sample point, which was then repeated over the 47-year simulation. The 3 years of data reported in the survey were represented in the model simulation as 1-, 2-, 3-, 4-, or 5-year crop rotations. For example, a 2-year corn-soybean rotation was used if the operator reported that corn was grown in the first year, soybeans in the second year, and corn again in the third year. In this case, only 2 of the reported 3 years of survey data were used. If management differed significantly for the 2 years that corn was grown (manure was applied, for example, or tillage was different), the rotation was expanded to 4 years, retaining the second year of corn and repeating the year of soybeans. In addition, some rotations with alfalfa or grass seed were simulated as 5-year rotations. Specific rules and procedures were established for using survey data to simulate cover crops, double crops, complex systems such as intercropping and nurse crops, perennial hay in rotations, abandoned crops, re-planting, multiple harvests, manure applications, irrigation, and grazing of cropland before and after harvest.[13]

Use of conservation practices in the Ohio-Tennessee River Basin was obtained from four sources: (1) NRI-CEAP Cropland Survey, (2) NRCS field offices, (3) USDA Farm Service Agency (FSA), and (4) the 2003 NRI. For each sample point, data from these four sources were pooled and duplicate practices discarded.[14]

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[10] The full theoretical and technical documentation of APEX can be found at http://epicapex.brc.tamus.edu/downloads/user-manuals.aspx.

[11] The I_APEX software steps through the simulations one at a time, extracting the needed data from the Access input tables, executes APEX, and then stores the model output in Access output files. The Web site for that software is http://www.card.iastate.edu/environment/interactive_programs.aspx.

[12] Summaries of APEX model validation studies on how well APEX simulates measured data are presented in Gassman et al. (2009) and in "APEX Model Validation for CEAP" found at http://www.nrcs.usda.gov/technical/nri/ceap.

[13] For a detailed description of the rules and procedures, see "Transforming Survey Data to APEX Model Input Files," http://www.nrcs.usda.gov/technical/nri/ceap.

[14] For a detailed description of the rules and procedures for simulation of structural conservation practices, see "Modeling Structural Conservation Practices in APEX," http://www.nrcs.usda.gov/technical/nri/ceap.

Simulating the No-Practice Scenario

The purpose of the no-practice scenario is to provide an estimate of sediment, nutrient, and pesticide loss from farm fields under conditions without the use of conservation practices. The benefits of conservation practices in use within the Ohio-Tennessee River Basin were estimated by contrasting model output from the no-practice scenario to model output from the baseline conservation condition (2003–06). The only difference between the no-practice scenario and the baseline conservation condition is that the conservation practices are removed or their effects are reversed in the no-practice scenario simulations. There were usually several alternatives that could be used to represent "no practices." The no-practice representations derived for use in this study conformed to the following guidelines.

- **Consistency:** It is impossible to determine what an individual farmer would be doing if he or she had not adopted certain practices, so it is important to represent all practices on all sample points in a consistent manner that is based on the intended purpose of each practice.

- **Simplicity:** Complex rules for assigning "no-practice" activities lead to complex explanations that are difficult to substantiate and sometimes difficult to explain and accept. Complexity would not only complicate the modeling process but also hamper the interpretation of results.

- **Historical context avoided:** The no-practice scenario is a technological step backward for conservation, not a chronological step back to a prior era when conservation practices were not used. Although the advent of certain conservation technologies can be dated, the adoption of technology is gradual, regionally diverse, and ongoing. It is also important to retain the overall crop mix in the region, as it in part reflects today's market forces. Therefore, moving the clock back to 1950s (or any other time period) agriculture is not the goal of the no-practice scenario. Taking away the conservation ethic is the goal.

- **Moderation:** The no-practice scenario should provide a reasonable level of inadequate conservation so that a reasonable benefit can be determined, where warranted, but not so severe as to generate exaggerated conservation gains by simulating the worst-case condition. Tremendous benefits could be generated if, for example, nutrients were applied at twice the recommended rates with poor timing or application methods in the no-practice simulation. Similarly, large erosion benefits could be calculated if the no-practice representation for tillage was fall plowing with moldboard plows and heavy disking, which was once common but today would generally be considered economically inefficient.

- **Maintenance of crop yield or efficacy**. It is impossible to avoid small changes in crop yields, but care was taken to avoid no-practice representations that would significantly change crop yields and regional production capabilities. The same guideline was followed for pest control—the suite of pesticides used was not adjusted in the no-practice scenario because of the likelihood that alternative pesticides would not be as effective and would result in lower yields under actual conditions.

A deliberate effort was made to adhere to these guidelines to the same degree for all conservation practices so that the overall level of representation would be equally moderate for all practices.

Table 11 summarizes the adjustments to conservation practices used in simulation of the no-practice scenario.

No-practice representation of structural practices

The no-practice field condition for structural practices is simply the removal of the structural practices from the modeling process. In addition, the soil condition is changed from "Good" to "Poor" for the determination of the runoff curve number for erosion prediction.

Overland flow. This group includes such practices as terraces and contouring which slow the flow of water across the field. For the practices affecting overland flow of water and therefore the P factor of the USLE-based equations, the P factor was increased to 1. Slope length is also changed for practices such as terraces to reflect the absence of these slope-interrupting practices.

Concentrated flow. This group of practices is designed to address channelized flow and includes grassed waterways and grade stabilization structures. These practices are designed to prevent areas of concentrated flow from developing gullies or to stabilize gullies that have developed. The no-practice protocol for these practices removes the structure or waterway and replaces it with a "ditch" as a separate subarea. This ditch, or channel, represents a gully; however, the only sediment contributions from the gully will come from downcutting. Headcutting and sloughing of the sides are not simulated in APEX.

Edge of field. These practices include buffers, filters, and other practices that occur outside the primary production area and act to mitigate the losses from the field. The no-practice protocol removes these areas and their management. When the practices are removed, the slope length is also restored to the undisturbed length that it would be if the practices were not in place. (When simulating a buffer in APEX, the slope length reported in the NRI is adjusted.)

Wind control. Practices such as windbreaks or shelterbelts, cross wind ridges, stripcropping or trap strips, and hedgerows are examples of practices used for wind control. The unsheltered distance reflects the dimensions of the field as modeled, 400 meters or 1,312 feet. Any practices reducing the unsheltered distance are removed and the unsheltered distance set to 400 meters.

Table 11. Construction of the no-practice scenario for the Ohio-Tennessee River Basin

Practice adjusted	Criteria used to determine if a practice was in use	Adjustment made to create the no-practice scenario
Structural practices	1. Overland flow practices present	1. USLE P-factor changed to 1 and slope length increased for points with terraces, soil condition changed from good to poor.
	2. Concentrated flow—managed structures or waterways present	2. Structures and waterways replaced with earthen ditch, soil condition changed from good to poor.
	3. Edge-of-field mitigation practices present	3. Removed practice and width added back to field slope length.
	4. Wind erosion control practices present	4. Unsheltered distance increased to 400 meters
Residue and tillage management	STIR ≤100 for any crop within a crop year	Add two tandem diskings 1 week prior to planting
Cover crop	Cover crop planted for off-season protection	Remove cover crop simulation (field operations, fertilizer, grazing, etc.)
Irrigation	Pressure systems	Change to hand-move sprinkler system except where the existing system is less efficient
Nitrogen rate	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.4 times harvest removal for non-legume crops, except for cotton and small grain crops	Increase rate to 1.7 times harvest removal (proportionate increase in all reported applications, including manure)
	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.6 times harvest removal for small grain crops	Increase rate to 2.0 times harvest removal (proportionate increase in all reported applications, including manure)
	Total of all applications of nitrogen (commercial fertilizer and manure applications) for cotton ≤60 pounds per bale	Increase rate to 90 pounds per bale (proportionate increase in all reported applications, including manure)
Phosphorus rate	Applied total of fertilizer and manure P over all crops in the crop rotation ≤ 1.1 times total harvest P removal over all crops in rotation.	Increase commercial P fertilizer application rates to reach 1.8 times harvest removal for the crop rotation (proportionate increase in all reported applications over the rotation), accounting also for manure P associated with any increase in manure applications to meet nitrogen application criteria for the no practice scenario. Manure applications were not further increased to meet the higher P rate for the no-practice scenario.
Commercial fertilizer application method	Incorporated or banded	Change to surface broadcast
Manure application method	Incorporated, banded, or injected	Change to surface broadcast
Commercial fertilizer application timing	Within 3 weeks prior to planting, at planting, or within 60 days after planting.	Moved to 3 weeks prior to planting. Manure applications were not adjusted for timing in the no-practice scenario.
Pesticides	1. Practicing high level of IPM	1. All incorporated applications changed to surface application. For each crop, the first application event after planting and 30 days prior to harvest replicated twice, 1 week and 2 weeks later than original.
	2. Practicing moderate level of IPM	2. Same as for high level of IPM, except replication of first application only 1 time, 1 week after original
	3. Spot treatments	3. Application rates for spot treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)
	4. Partial field treatments	4. Application rates for partial field treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)

No-practice representation of conservation tillage

The no-practice tillage protocols are designed to remove the benefits of conservation tillage. For all crops grown with some kind of reduced tillage, including cover crops, the no-practice scenario simulates conventional tillage, based on the STIR (Soil Tillage Intensity Rating) value. Conventional tillage for the purpose of estimating conservation benefits is defined as any crop grown with a STIR value above 100. (To put this in context, no-till or direct seed systems have a STIR of less than 30, and that value is part of the technical standard for Residue Management, No-Till/Strip Till/Direct Seed [NRCS Practice Standard 329]). Those crops grown with a STIR value of less than 100 in the baseline conservation condition had tillage operations added in the no-practice scenario.

Simulating conventional tillage for crops with a STIR value of less than 100 requires the introduction of additional tillage operations in the field operations schedule. For the no-practice scenario, two consecutive tandem disk operations were added prior to planting. In addition to adding tillage, the hydrologic condition for assignment of the runoff curve number was changed from good to poor on all points receiving additional tillage. Points that are conventionally tilled for all crops in the baseline condition scenario are also modeled with a "poor" hydrologic condition curve number.

The most common type of tillage operation in the survey was disking, and the most common disk used was a tandem disk for nearly all crops, in all parts of the region, and for both dryland and irrigated agriculture. The tandem disk has a STIR value of 39 for a single use. Two consecutive disking operations will add 78 to the existing tillage intensity, which allows for more than 90 percent of the crops to exceed a STIR of 100 and yet maintain the unique suite and timing of operations for each crop in the rotation. Although a few sample points will have STIR values in the 80s or 90s after adding the two disking operations, the consistency of an across-the-board increase of 78 is simple and provides the effect of a distinctly more intense tillage system.

These additional two tillage operations were inserted in the simulation one week prior to planting, one of the least vulnerable times for tillage operations because it is close to the time when vegetation will begin to provide cover and protection.

No-practice representation of cover crops

The no-practice protocol for this practice removes the planting of the crop and all associated management practices such as tillage and fertilization. In a few cases the cover crops were grazed; when the cover crops were removed, so were the grazing operations.

No-practice representation of irrigation practices

The no-practice irrigation protocols were designed to remove the benefits of better water management and the increased efficiencies of modern irrigation systems. Irrigation efficiencies are represented in APEX by a combination of three coefficients that recognize water losses from the water source to the field, evaporation losses with sprinkler systems, percolation losses below the root-zone during irrigation, and runoff at the lower end of the field. These coefficients are combined to form an overall system efficiency that varies with soil type and land slope.

The quantity of water applied for all scenarios was simulated in APEX using an "auto-irrigation" procedure that applied irrigation water when the degree of plant stress exceeded a threshold. "Auto-irrigation" amounts were determined within pre-set single event minimums and maximums, and an annual maximum irrigation amount. APEX also used a pre-determined minimum number of days before another irrigation event regardless of plant stress.

In the no-practice representation, all conservation practices, such as Irrigation Water Management and Irrigation Land Leveling, were removed and samples with pressurized systems, such as center pivot, side roll, and low flow (drip), were changed to "hand move sprinklers," which represents an early form of pressure system with connecting pipes. The "Big Gun" systems, which make up 9 percent of the irrigated acres, are by and large already less efficient than the "hand move sprinklers," and most were not converted. However, 4.2 percent of the irrigated acres that were served by "Big Gun" systems are more efficient than the "hand move sprinklers," and these were converted in the no-practice representation.

Thus, for the no-practice scenario, 94.8 percent of irrigated acreage was simulated using hand-move lines with impact sprinkler heads and 5.2 percent retained the Big Gun systems that were in use.

No-practice representation of nutrient management practices

The no-practice nutrient management protocols are designed to remove the benefits of proper nutrient management techniques.

The NRCS Nutrient Management standard (590) allows a variety of methods to reduce nutrient losses while supplying a sufficient amount of nutrient to meet realistic yield goals. The standard addresses nutrient loss in two primary ways: (1) by altering rates, form, timing, and methods of application, and (2) by installing buffers, filters, or erosion or runoff control practices to reduce mechanisms of loss. The latter method is covered by the structural practices protocols for the no-practice scenario. The goals of the nutrient management no-practice protocols are to alter three of the four basic aspects of nutrient application—rate, timing, and method. The form of application was not addressed because of the inability to determine if proper form was being applied.

Commercial nitrogen fertilizer rate. For the no-practice scenario, the amount of commercial nitrogen fertilizer applied was—

- increased to 1.70 times harvest removal for non-legume crops receiving less than or equal to 1.4 times the amount

of nitrogen removed at harvest in the baseline scenario, except for cotton and small grain crops;

- increased to 2.0 times harvest removal for small grain crops receiving less than or equal to 1.6 times the amount of nitrogen removed at harvest in the baseline scenario, and
- increased to 90 pounds per bale for cotton crops receiving less than 60 pounds of nitrogen per bale in the baseline scenario.

The ratio of 1.70 for the increased nitrogen rate was determined by the average rate-to-yield-removal ratio for crops exceeding the application-removal ratio of 1.4. Where nitrogen was applied in multiple applications, each application was increased proportionately.

The assessment was made on an average annual basis for each crop in the rotation using average annual model output on nitrogen removed with the yield at harvest in the baseline conservation condition scenario.

Commercial phosphorus fertilizer rate. The threshold for identifying proper phosphorus application rates was 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. The threshold is lower for phosphorus than for nitrogen because phosphorus is not lost through volatilization to the atmosphere and much less is lost through other pathways owing to strong bonding of phosphorus to soil particles.

For the no-practice scenario, the amount of commercial phosphorus fertilizer applied was increased to 1.8 times the harvest removal rate for the crop rotation. The ratio of 1.8 for the increased phosphorus rate was determined by the average rate-to-yield-removal ratio for crops with phosphorus applications exceeding 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. Multiple commercial phosphorus fertilizer applications were increased proportionately to meet the 1.8 threshold.

Manure application rate. For sites receiving manure, the appropriate manure application rate in tons per acre was identified on the basis of the total nitrogen application rate, including both manure and commercial nitrogen fertilizer. Thus, if the total for all applications of nitrogen (commercial fertilizer and manure) was less than or equal to 1.4 times removal at harvest for non-legume crops, the no-practice manure application rate was increased such that the combination of commercial fertilizer and manure applications resulted in a total rate of nitrogen application equal to 1.7 times harvest removal. Both commercial nitrogen fertilizer and the amount of manure were increased proportionately to reach the no-practice scenario rate. For small grains and cotton, the same approach was used using the criteria defined above for commercial nitrogen fertilizer. As done with commercial nitrogen fertilizer, the assessment was made separately for each crop in the rotation.

Any increase in phosphorus from manure added to meet the nitrogen criteria for the no-practice scenario was taken into account in setting the no-practice commercial phosphorus fertilizer application rate.

Thus, no adjustment was made to manure applied at rates below the P threshold of 1.1 in the no-practice scenario because the manure application rate was based on the nitrogen level in the manure.

Timing of application. Nutrients applied closest to the time when a plant needs them are the most efficiently utilized and least likely to be lost to the surrounding environment. All commercial fertilizer applications occurring within 3 weeks prior to planting, at planting, or within 60 days after planting were moved back to 3 weeks prior to planting for the no-practice scenario. For example, split applications that occur within 60 days after planting are moved to a single application 3 weeks before planting for the no-practice scenario.

Timing of manure applications was not adjusted in the no-practice scenario.

Method of application. Nutrient applications, including manure applications, that were incorporated or banded were changed to a surface broadcast application method for the no-practice scenario.

No-practice representation of pesticide management practices

Pesticide management for conservation purposes is a combination of three types of interrelated management activities:

1. A mix of soil erosion control practices that retain pesticide residues within the field boundaries.
2. Pesticide use and application practices that minimize the risk that pesticide residues pose to the surrounding environment.
3. Practice of Integrated Pest Management (IPM), including partial field applications and spot treatment.

The first activity is covered by the no-practice representation of structural practices and residue and tillage management. The second activity, for the most part, cannot be simulated in large-scale regional modeling because of the difficulty in assuring that any changes in the types of pesticides applied or in the method or timing of application would provide sufficient protection against pests to maintain crop yields.[15] Farmers, of course, have such options, and environmentally conscientious farmers make tradeoffs to reduce environmental risk. But without better information on the nature of the pest problem both at the field level and in the surrounding area, modelers have to resort to prescriptive and generalized approaches to simulate alternative pesticides and application

[15] The APEX model can simulate pesticide applications, but it does not currently include a pest population model that would allow simulation of the effectiveness of pest management practices. Thus, the relative effectiveness of pesticide substitution or changes in other pest management practices cannot be evaluated.

techniques, which would inevitably be inappropriate for many, if not most, of the acres simulated.

The no-practice representation for pesticide management is therefore based on the third type of activity—IPM.

One of the choices for methods of pesticide application on the survey was “spot treatment.” Typically, spot treatments apply to a small area within a field and are often treated using a hand-held sprayer. Spot treatment is an IPM practice, as it requires scouting to determine what part of the field to treat and avoids treatment of parts of the field that do not have the pest problem. The reported rate of application for spot treatments was the rate per acre treated. For the baseline simulation, it was assumed that all spot treatments covered 5 percent of the field. Since the APEX model run and associated acreage weight for the sample point represented the whole field, the application rate was adjusted downward to 5 percent of the per-acre rate reported for the baseline scenario. For the no-practice scenario, the pesticide application rate as originally reported was used, simulating treatment of the entire field rather than 5 percent of the field. In the Ohio-Tennessee River Basin, there were 23 sample points with spot treatments, representing 1.4 percent of the cropped acres.

Partial field treatments were simulated in a manner similar to spot treatments. Partial field treatments were determined using information reported in the survey on the percentage of the field that was treated. (Spot treatments, which are also partial field treatments, were treated separately as described above.) For the baseline scenario, application rates were reduced proportionately according to how much of the field was treated. For the no-practice scenario, the rate as reported in the survey was used, simulating treatment of the entire field. However, this adjustment for the no-practice scenario was only done for partial field treatments on less than one-third of the field, as larger partial field treatments could have been for reasons unrelated to IPM. About one percent of the cropped acres in the Ohio-Tennessee River Basin had partial field treatments of pesticides.

The IPM indicator, described in the previous chapter, was used to adjust pesticide application methods and to increase the frequency of applications to represent “no IPM practice.” For samples classified as having either high or moderate IPM use, all soil-incorporated pesticide applications in the baseline condition were changed to surface applications in the no-practice scenario. For high IPM cases, the first application event between planting and 30 days before harvest was replicated twice for each crop, 1 week and 2 weeks after its original application. For moderate IPM cases, the first application event was replicated one time for each crop, 1 week after its original application.

No-practice representation of land in long-term conserving cover

The no-practice representation of land in long-term conserving cover is cultivated cropping with no conservation practices in use. For each CRP sample point, a set of cropping simulations was developed to represent the probable mix of management that would be applied to the point if it were cropped. Cropped sample points were matched to each CRP sample point on the basis of slope, soil texture, soil hydrologic group, and geographic proximity. The cropped sample points that matched most closely were used to represent the cropped condition that would be expected at each CRP sample point if the field had not been enrolled in CRP. In most cases, seven “donor” points were used to represent the crops that were grown and the various management activities to represent crops and management for the CRP sample point “as if” the acres had not been enrolled in CRP. The crops and management activities of each donor crop sample were combined with the site and soil characteristics of the CRP point for the no-practice representation of land in long-term conserving cover.

Effects of Practices on Fate and Transport of Water

Water is a potent force that interacts with or drives almost all environmental processes acting within an agricultural production system. The hydrologic conditions prevalent in the Ohio-Tennessee River Basin are critical to understanding the estimates of sediment, nutrient, and pesticide loss presented in subsequent sections. The APEX model simulates hydrologic processes at the field scale—precipitation, irrigation, evapotranspiration, surface water runoff, infiltration, subsurface flows, and percolation beyond the bottom of the soil profile.

Baseline condition for cropped acres

Precipitation and irrigation are the sources of water for a field. Annual precipitation over the 47-year simulation averaged about 42 inches in this region (table 12). (Also see figs. 5 and 6.) Only about 1 percent of cropped acres are irrigated, at an average application rate of 11 inches per year.

Most of the water that leaves the field is lost through evaporation from the soil and plant surfaces and transpiration by plants (evapotranspiration) (fig. 13). Evapotranspiration is the dominant loss pathway for 99 percent of cropped acres. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) On average, about 60 percent of the water loss for cropped acres in this region is through evapotranspiration (table 12). Model results indicate that evapotranspiration losses vary, however, according to soil characteristics and land cover; evapotranspiration ranges from about 50 percent to 70 percent of the total amount of water that leaves the field (fig. 14).

Subsurface flow pathways are the second largest source of water loss at an average of about 9 inches per year for cropped acres, on average (table 12). Subsurface flow pathways include—

1. deep percolation to groundwater, including groundwater return flow to surface water,
2. subsurface flow that is intercepted by tile drains or drainage ditches, when present, and
3. lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

The percentage of water loss represented by subsurface flows averages about 22 percent for cropped acres (table 12). However, this percentage varies from less than 10 percent to over 30 percent for cropped acres in the Ohio-Tennessee River Basin, as shown in figure 14.

Surface water runoff averages about 18 percent of water loss for cropped acres (table 12), ranging from about 5 percent to 30 percent (fig. 14). Average surface water loss for cropped acres is about 7.6 inches per year (table 12). The amount of surface water runoff varies from acre to acre, ranging from an annual average of about 4 inches per year to about 14 inches per year (fig. 13).

Figure 13. Estimates of average annual water lost through three loss pathways for cropped acres in the Ohio-Tennessee River Basin, baseline conservation condition

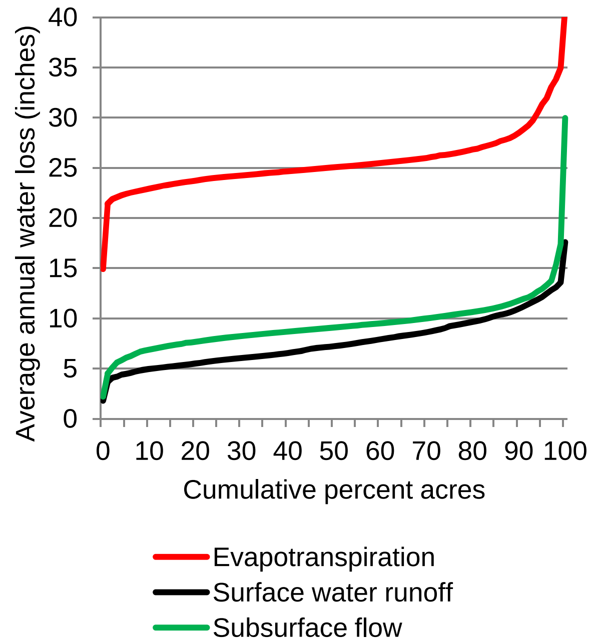
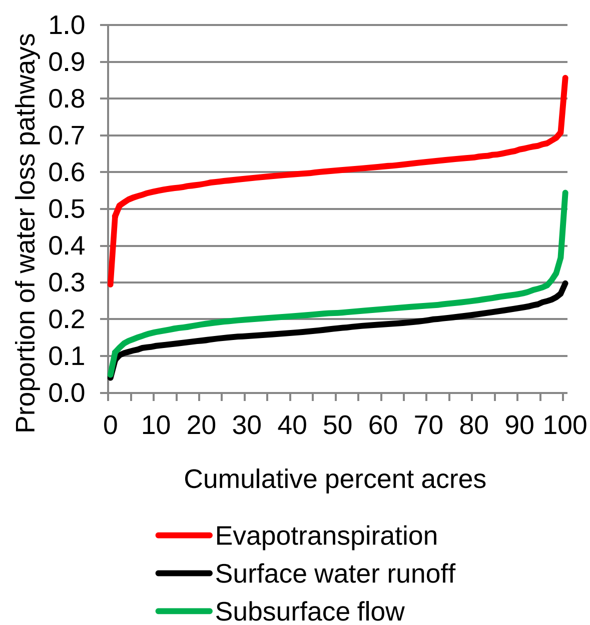


Figure 14. Cumulative distributions of the proportion of water lost through three loss pathways for cropped acres, Ohio-Tennessee River Basin, baseline conservation condition



Note: The horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same acres on another curve.

Table 12. Field-level effects of conservation practices on water loss pathways for cultivated cropland in the Ohio-Tennessee River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (25.0 million acres)				
Water sources				
Non-irrigated acres				
Average annual precipitation (inches)	42.0	42.0	0.0	0
Irrigated acres				
Average annual precipitation (inches)	43.3	43.3	0.0	0
Average annual irrigation water applied (inches)*	11.2	19.5	8.3	43
Water loss pathways				
Average annual evapotranspiration (inches)	25.5	25.8	0.2	1
Average annual surface water runoff (inches)	7.6	8.3	0.7	8
Average annual subsurface water flows (inches)**	9.3	8.4	-0.9***	-11***
Land in long-term conserving cover (0.8 million acres)				
Water sources*				
Average annual precipitation (inches)	44.8	44.8	0.0	0
Average annual irrigation water applied (inches)*	0.0	0.1	0.1	100
Water loss pathways				
Average annual evapotranspiration (inches)	25.9	26.3	0.4	2
Average annual surface water runoff (inches)	7.2	10.1	2.9	29
Average annual subsurface water flow (inches)**	12.2	8.6	-3.6***	-42***

* About 1 percent of the cropped acres in the Ohio-Tennessee River Basin are irrigated. Land in long-term conserving cover was not irrigated, but some farming practices used to simulate a cropped condition to represent the no-practice scenario included irrigation. Values shown in the table for land in long-term conserving cover are averages over all acres, including non-irrigated acres.
** Subsurface flow pathways include: (1) deep percolation to groundwater, including groundwater return flow; (2) subsurface flow intercepted by tile drains or drainage ditches; (3) lateral subsurface outflow; and (4) quick-return subsurface flow.
*** Represents an average gain in subsurface flows of 0.9 inch per year (11 percent increase) for cropped acres due to the use of conservation practices; represents an average gain of 3.6 inches in subsurface flow for land in long-term conserving cover.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 18 subregions.

Tile Drainage

Tile drainage flow is included in the water loss category "subsurface water flows" in this report. (See table 12.) Other components of subsurface water flow include: 1) deep percolation to groundwater, including groundwater return flow to surface water, 2) lateral subsurface flows intercepted by surface drainage ditches, and 3) lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

While the farmer survey provided information on whether or not the field with the CEAP sample point had tile drainage, tile drainage flow and loss of soluble nutrients in tile drainage water are not reported separately because other important information on the tile drainage characteristics were not covered in the survey. The missing information includes—

- the depth and spacing of the tile drainage field,
- the extent of the tile drainage network,
- the proportion of the field, or other fields, that benefited from the tile drainage system, and
- the extent to which overland flow and subsurface flow from surrounding areas enters through tile surface inlets.

Without this additional information, it is not possible to accurately separate out the various components of subsurface flow when tile drainage systems are present.

In the Ohio-Tennessee River basin, about half of the cropped acres have some portion of the field that is tile drained, according to the farmer survey. For these acres, about three-fourths of the subsurface flow in the baseline—as well as the soluble nutrients carried in the subsurface flow—was allocated by the physical process model (APEX) to tile drainage flow in this region.

Effects of conservation practices on cropped acres

Structural water erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil.[16] Model simulations indicate that conservation practices have reduced surface water runoff by about 0.7 inch per year averaged over all acres, representing an 8-percent reduction for the region (table 12).

The re-routing of surface water to subsurface flows is shown graphically in figures 15 and 16 for cropped acres. The no-practice scenario curve in figure 15 shows what the distribution of surface water runoff would be if there were no conservation practices in use— more surface water runoff and thus less subsurface flow and less soil moisture available for crop growth.

Reductions in surface water runoff due to conservation practices range from less than zero to above 1.5 inches per year for most cropped acres in the region (fig. 16). The variability in reductions due to practices reflects different levels of conservation treatment as well as differences in precipitation and inherent differences among acres for water to run off.

Use of improved irrigation systems in the Ohio-Tennessee River Basin increases irrigation efficiency from 41 percent in the no-practice scenario to 62 percent in the baseline scenario. This change in efficiency represents an annual decreased need for irrigation water of 8 inches per year where irrigation is used (table 12).

Land in long-term conserving cover

Model simulations further show that land in long-term conserving cover (baseline conservation condition) in the region also has, on average, less surface water runoff and more subsurface flow than would occur if the land was cropped (table 12).

Reductions in surface water runoff due to conversion to long-term conserving cover average 2.9 inches per year in this region (table 12), but range from less than 1 inch to above 6 inches per year for some acres (fig. 17).

[16] Model simulations did not include increased infiltration for some structural practices—model parameter settings conservatively prevented infiltration of run-on water and its dissolved contaminants in conservation buffers including field borders, filter strips and riparian forest buffers.

Figure 15. Estimates of average annual surface water runoff for cropped acres in the Ohio-Tennessee River Basin

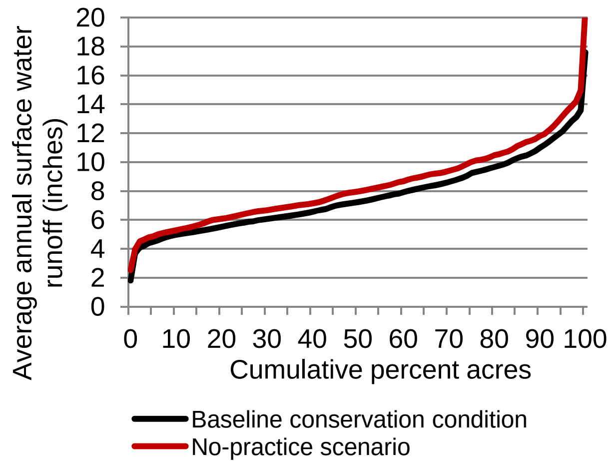
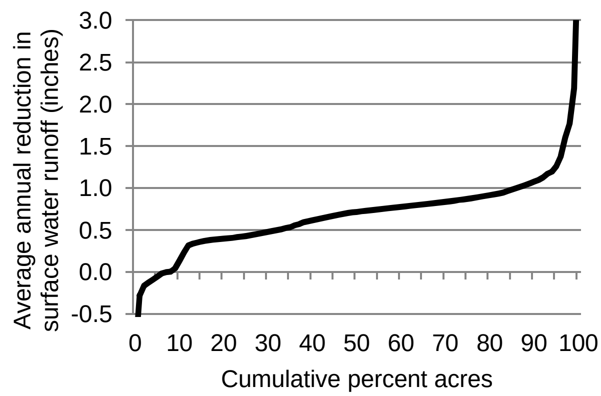
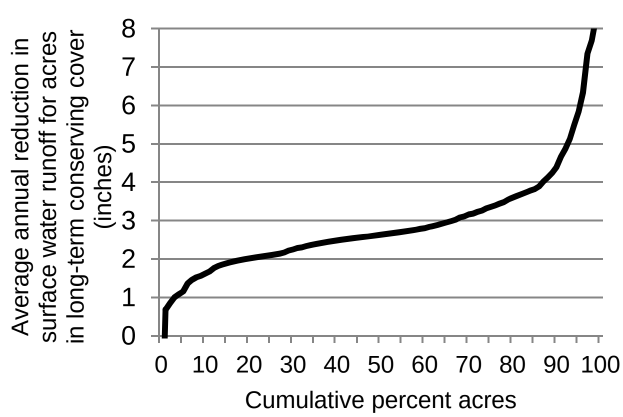


Figure 16. Estimates of average annual reduction in surface water runoff due to the use of conservation practices on cropped acres in the Ohio-Tennessee River Basin



Note: About 6 percent of cropped acres had less surface water runoff in the no-practice scenario than the baseline, resulting in negative reductions. These gains in surface water runoff when conservation practices are applied can occur on soils with low to moderate potential for runoff when: (1) excessive nutrient application rates in the no-practice scenario produces more biomass, lowering soil moisture and thus reducing runoff, or (2) tillage of the surface soil in the no-practice scenario reduces surface compaction and crusting, producing temporary surface roughness that in turn reduces runoff.

Figure 17. Estimates of average annual reduction in surface water runoff due to conversion to long-term conserving cover in the Ohio-Tennessee River Basin



Cumulative Distributions Show How Effects of Conservation Practices Vary Throughout the Region

The design of this study provides the opportunity to examine not only the overall mean value for a given outcome, but also the entire distribution of outcomes. This is possible because outcomes are estimated for each of the 2,124 sample points used to represent cropped acres in the Ohio-Tennessee River Basin and for each of the 559 sample points used to represent land in long-term conserving cover. Cumulative distributions show the full set of estimates and thus demonstrate how conditions and the effects of conservation practices vary throughout the region.

Cumulative distributions shown in this report are plots of the value for each percentile. In figure 15, for example, the curve for average annual surface water runoff for the baseline conservation condition consists of each of the percentiles of the distribution of 2,124 surface water runoff estimates, weighted by the acres associated with each sample point. The 10th percentile for the baseline conservation condition is 5 inches per year, indicating that 10 percent of the acres have 5 inches or less of surface water runoff, on average. Similarly, the same curve shows that 25 percent of the acres have surface water runoff less than 5.8 inches per year. The 50th percentile—the median—is 7.2 inches per year, which in this case is close to the mean value of 7.6 inches per year. At the high end of the distribution, 90 percent of the acres in this region have surface water runoff less than 11 inches per year; and conversely, 10 percent of the acres have surface water runoff greater than 11 inches per year.

Thus, the distributions show the full range of outcomes for cultivated cropland acres in the Ohio-Tennessee River Basin . The full range of outcomes for the baseline condition is compared to that for the no-practice scenario in figure 15 to illustrate the extent to which conservation practices reduce surface water runoff throughout the region.

Figure 16 shows the effects of conservation practices on surface water runoff using the distribution of the *reduction* in surface water runoff, calculated as the outcome for the no-practice scenario minus the outcome for the baseline conservation condition at each of the 2,124 cropped sample points. This distribution shows that, while the mean reduction is 0.7 inch per year, 15 percent of the acres have reductions due to conservation practices greater than one inch per year and 6 percent of the acres actually have small increases in surface water runoff (i.e., negative reductions) as a result of soil erosion control conservation practice use. (See footnote to figure 16 for an explanation of the conditions that result in gains in surface water runoff due to conservation practices.)

Effects of Practices on Wind Erosion

Wind velocity, tillage, vegetative cover, and the texture and structure of the soil are primary determinants of wind erosion. Wind erosion removes the most fertile parts of the soil such as the lighter, less dense soil constituents including organic matter, clays, and silts. Wind erosion occurs when the soil is unprotected and wind velocity exceeds about 13 miles per hour near the surface. Wind erosion is estimated in APEX using the Wind Erosion Continuous Simulation (WECS) model. The estimated wind erosion rate is the amount of eroded material leaving the downwind edge of the field.

Wind erosion is not a significant resource concern in the Ohio-Tennessee River Basin. The greatest concern with wind erosion in this region is crop damage to young seedlings exposed to windblown material. Wind erosion rates as low as 0.5 ton per acre have been known to cause physical damage to young seedlings.

Baseline condition for cropped acres

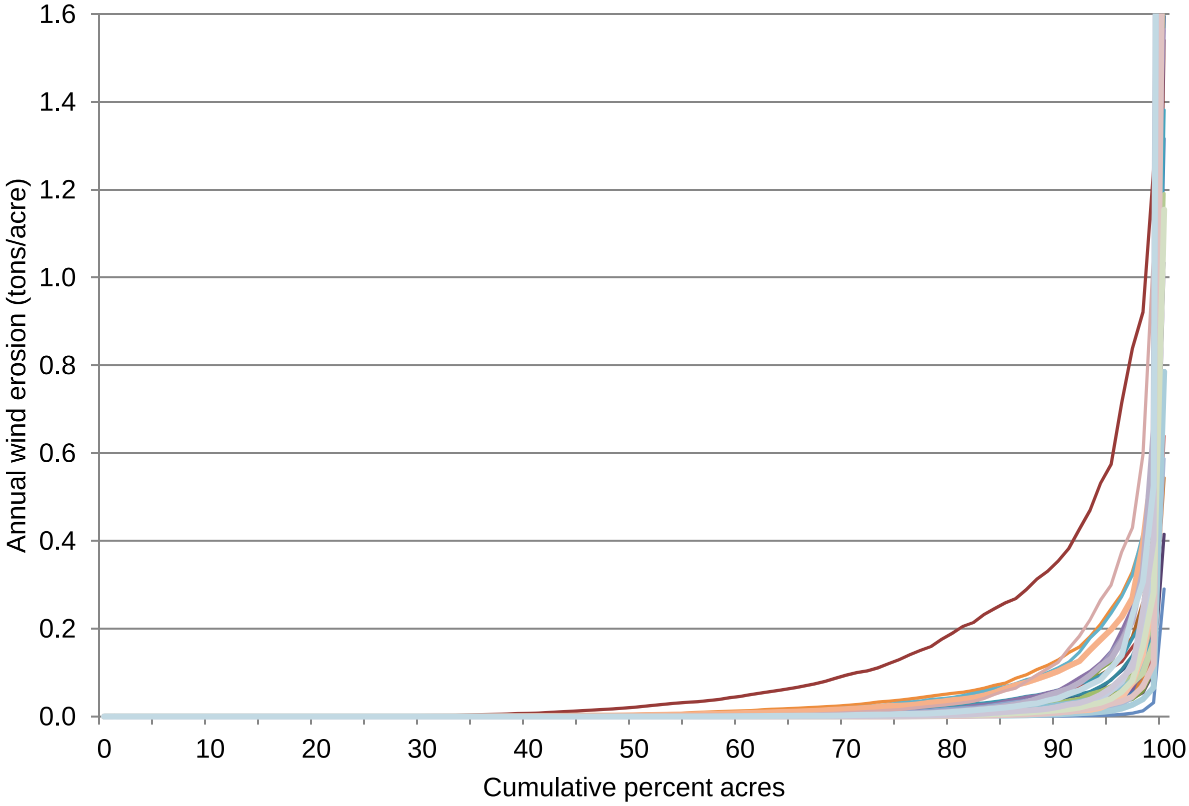
For all cropped acres, model simulations show that the average annual rate of wind erosion is 0.02 ton per acre (table 13). In some years, however, annual wind erosion can exceed 0.5 ton per acre on some acres in the region (fig. 18). Average annual wind erosion is below 0.1 ton per acre on nearly all cropped acres (fig. 19)

Table 13. Average annual wind erosion (tons/acre) for cultivated cropland in the Ohio-Tennessee River Basin

	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres	0.020	0.052	0.031	60
Land in long-term conserving cover	<0.0001	0.007	0.007	100

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 18 subregions.

Figure 18. Distribution of annual wind erosion rate for each year of the 47-year model simulation, Ohio-Tennessee River Basin



Note: This figure shows how annual wind erosion (tons per acre per year) varies within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual wind erosion varies over the region in that year, starting with the acres with the lowest rates and increasing to the acres with the highest rates. The family of curves shows how annual wind erosion rates vary from year to year.

Effects of conservation practices

Farmers address wind erosion using conservation practices designed to enhance the soil's ability to resist and reduce the wind velocity near the soil surface. Properly planned and applied residue management reduces wind erosion by leaving more organic material on the soil surface, which in turn helps preserve soil aggregate stability and promotes further aggregation. Physical barriers such as windbreaks or shelterbelts, herbaceous wind barriers or windbreaks, cross wind trap strips, or ridges constructed perpendicular to the prevailing wind direction also reduce the intensity of wind energy at the surface. Row direction or arrangement, surface roughening, and stripcropping also lessen the wind's energy.

Structural practices for wind erosion control are in use on only 2 percent of the cropped acres in the Ohio-Tennessee River Basin. However, other practices common in the region, such as residue and tillage management, reduced tillage, and various water erosion control practices, are also effective in reducing wind erosion. Model simulations indicate that conservation practices have reduced the average wind erosion rate by 60 percent in the region (table 13).

Without conservation practices, the average annual wind erosion would have been 0.05 ton per acre per year compared to 0.02 ton per acre average for the baseline conservation condition. On average, conservation practices have reduced wind erosion by 0.03 ton per acre. Reductions in wind erosion due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil (fig. 20).

Figure 19. Estimates of average annual wind erosion for cropped acres in the Ohio-Tennessee River Basin

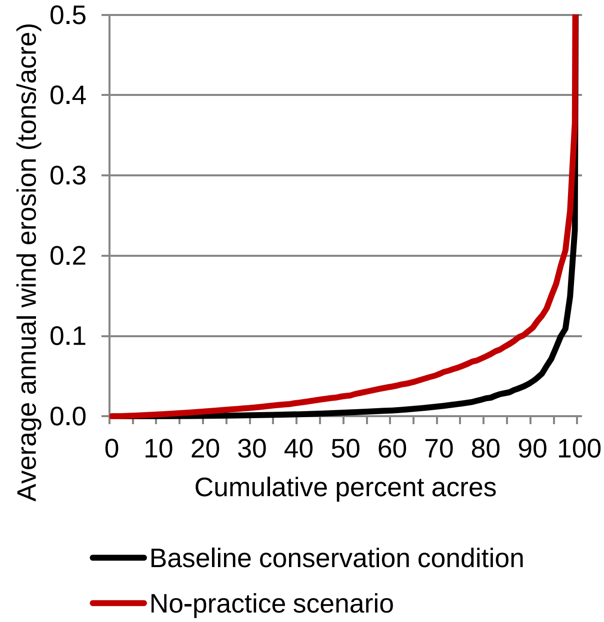
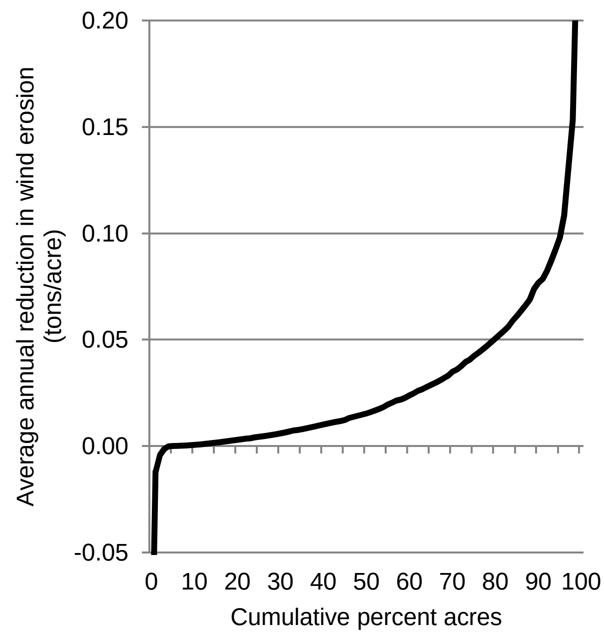


Figure 20 Estimates of average annual reduction in wind erosion due to the use of conservation practices on cropped acres in the Ohio-Tennessee River Basin



Effects of Practices on Water Erosion and Sediment Loss

Sheet and rill erosion is the detachment and movement of soil particles within the field that occurs during rainfall events. Controlling sheet and rill erosion is important for sustaining soil productivity and preventing soil from leaving the field.

The term "sediment loss," as used in this report, refers to the sediment that is transported beyond the edge of the field by water. Soil erosion and sedimentation are separate but interrelated resource concerns. Soil erosion is the detachment and transport of soil particles, while sedimentation is that portion of the eroded material that settles out in areas onsite or offsite. Sediment loss, as estimated in this study, includes the portion of the sheet and rill eroded material that settles offsite as well as some sediment that originates from gully erosion processes.[17] Edge-of-field conservation practices are designed to filter out a portion of the material and reduce sediment loss. Sediment is composed of detached and transported soil minerals, organic matter, plant and animal residues, and associated chemical and biological compounds.

The proportion of cropped acres that is classified as highly erodible for water erosion in this region—27 percent—is close to the national average of 28 percent. Most of these soils have silty textured surfaces derived from loess deposits over glacial deposits in the northern portions of the basin and loess over residuum from mainly sedimentary rocks in the southern portions. Soils with appreciable silt contents are typically the most susceptible to erosion.

Sheet and rill erosion

Model simulations show that sheet and rill erosion on cropped acres in the Ohio-Tennessee River Basin averages about 1.1 tons per acre per year (table 14). Sheet and rill erosion rates are higher for highly erodible land, averaging 2.4 tons per acre per year compared to the average annual rate for non-highly erodible land of 0.7 ton per acre.

Model simulation results also show that conservation practices have reduced sheet and rill erosion on cropped acres in the Ohio-Tennessee River Basin by an average of 0.76 ton per acre per year, representing a 40-percent reduction on average (table 14). While the average annual reduction in sheet and rill erosion for highly erodible land is more than three times that for non-highly erodible acres (table 14), the percent reduction due to conservation practices is about the same.

For land in long-term conserving cover, sheet and rill erosion has been reduced from 4.4 tons per acre per year if cropped without conservation practices to 0.12 ton per acre (table 14), on average.

Sediment loss from water erosion

Baseline condition for cropped acres. The average annual sediment loss for cropped acres in the Ohio-Tennessee River Basin is 1.6 tons per acre per year, according to the model simulation (table 14). As seen for sheet and rill erosion, sediment loss for highly erodible land is much higher than for non-highly erodible land, even though a higher proportion of highly erodible acres have structural water erosion control practices in use.

On an annual basis, sediment loss can vary from year to year, although high losses are restricted to a minority of the acres. Figure 21 shows that, with the conservation practices currently in use in the Ohio-Tennessee River Basin, annual sediment loss is below 2 tons per acre for about 65 percent of the acres under all conditions, including years with high precipitation. In contrast, sediment loss exceeds 6 tons per acre in one or more years on about 13 percent of the cropped acres.

Figure 21 also illustrates the extent to which high sediment losses are restricted to a minority of acres within the region, even during years with high precipitation. These are the acres that have the highest inherent vulnerability to water erosion and have inadequate soil erosion control.

Effects of conservation practices on cropped acres. Model simulations indicate that the use of conservation practices in the Ohio-Tennessee River Basin has reduced average annual sediment loss from water erosion by 52 percent for cropped acres in the region, including both treated and untreated acres (table 14). Without conservation practices, the average annual sediment loss for these acres would have been 3.3 tons per acre per year compared to 1.6 tons per acre average for the baseline conservation condition. Figure 22 shows that about 43 percent of the acres would have more than 2 tons per acre per year sediment loss without practices, on average, compared to 18 percent with conservation practices.

Reductions in sediment loss due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil. For about 25 percent of cropped acres, the average annual sediment loss reduction due to practices is less than 0.25 ton per acre (fig. 23). The top 10 percent of the acres had reductions in average annual sediment loss greater than 4 tons per acre.

Cropped acres with a combination of structural practices and residue and tillage management have the highest percent reduction in sediment loss (table 15). Acres that are treated with structural practices, meet tillage intensity criteria for no-till or mulch till, and are gaining soil organic carbon (about 23 percent of cropped acres) have reduced sediment loss by 79 percent, on average. For these treated acres, annual sediment loss averages only about 0.6 ton per acre in this region.

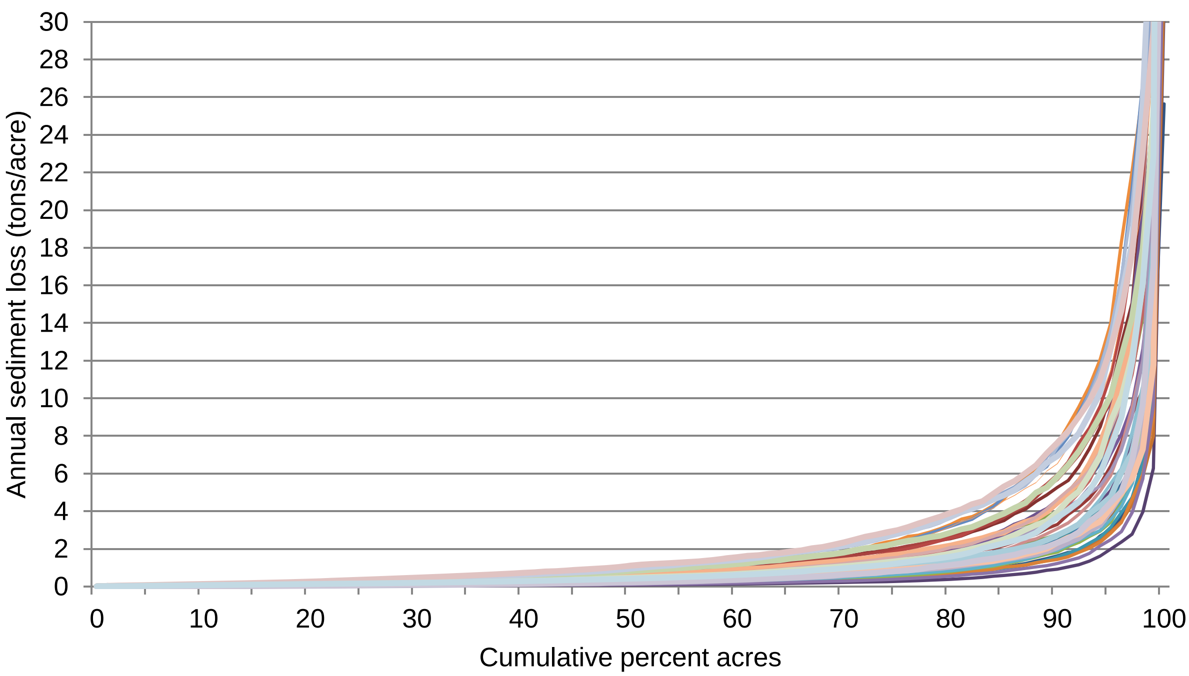
[17] For this study, the APEX model was set up to estimate sediment loss using a modified version of USLE, called MUSS, which uses an internal sediment delivery ratio to estimate the amount of eroded soil that actually leaves the boundaries of the field. A large percentage of the eroded material is redistributed and deposited within the field or trapped by buffers and other conservation practices and does not leave the boundary of the field, which is taken into account in the sediment delivery calculation. The estimate also includes some gully erosion and some ephemeral gully erosion. For this reason, sediment loss rates can exceed sheet and rill erosion rates.

Table 14. Field-level effects of conservation practices on erosion and sediment loss for cultivated cropland in the Ohio-Tennessee River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (25.0 million acres)				
Average annual sheet and rill erosion (tons/acre)*	1.14	1.90	0.76	40
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	1.59	3.29	1.70	52
Highly erodible land (27 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	2.39	3.91	1.52	39
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	3.68	7.45	3.76	51
Non-highly erodible land (73 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	0.69	1.17	0.48	41
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.83	1.78	0.95	53
Land in long-term conserving cover (0.8 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.12	4.40	4.28	97
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.18	8.24	8.06	98

* Estimated using the Revised Universal Soil Loss Equation.
**Estimated using MUSS, which includes some sediment from gully erosion. See text.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 18 subregions.

Figure 21. Distribution of annual sediment loss for each year of the 47-year model simulation, Ohio-Tennessee River Basin



Note: This figure shows how annual sediment loss (tons per acre per year) varies within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual sediment loss varies over the region in that year, starting with the acres with the lowest sediment loss and increasing to the acres with the highest sediment loss. The family of curves shows how annual sediment loss varies from year to year.

Figure 22. Estimates of average annual sediment loss for cropped acres in the Ohio-Tennessee River Basin

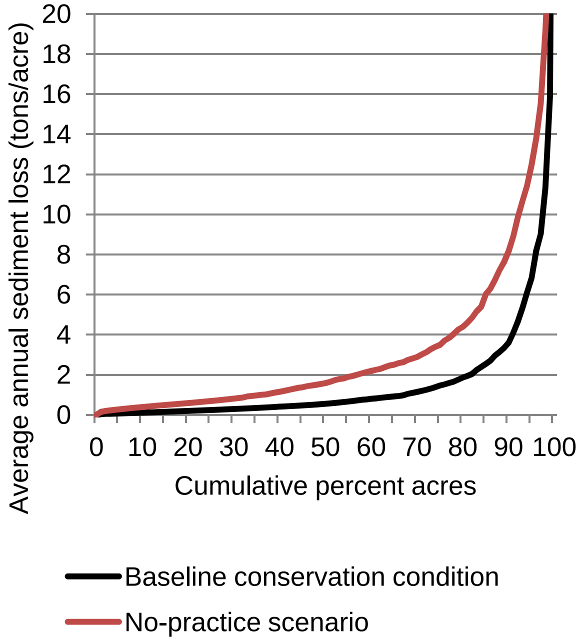
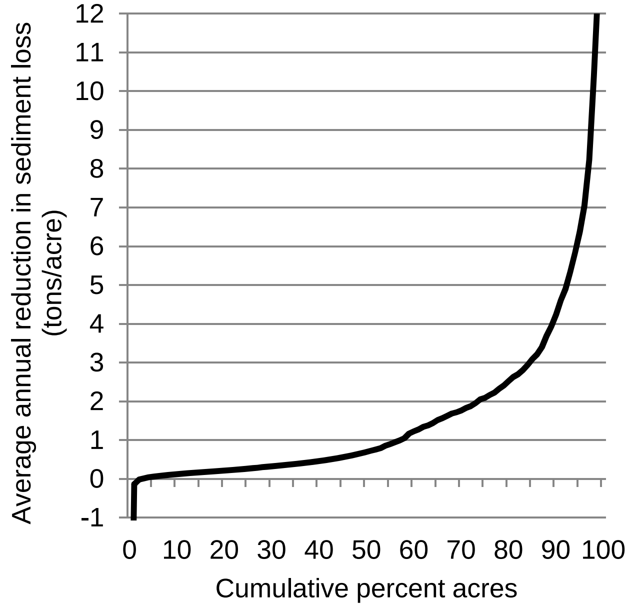


Figure 23. Estimates of average annual reduction in sediment loss due to the use of conservation practices on cropped acres in the Ohio-Tennessee River Basin



Note: About 2 percent of the acres had less sediment loss in the no-practice scenario than the baseline conservation condition, resulting from the increase is surface water runoff on some acres due to conservation practices. See footnote to figure 16.

Table 15. Estimates of effects of combinations of structural practices and residue and tillage management on average annual sediment loss for cropped acres in the Ohio-Tennessee River Basin

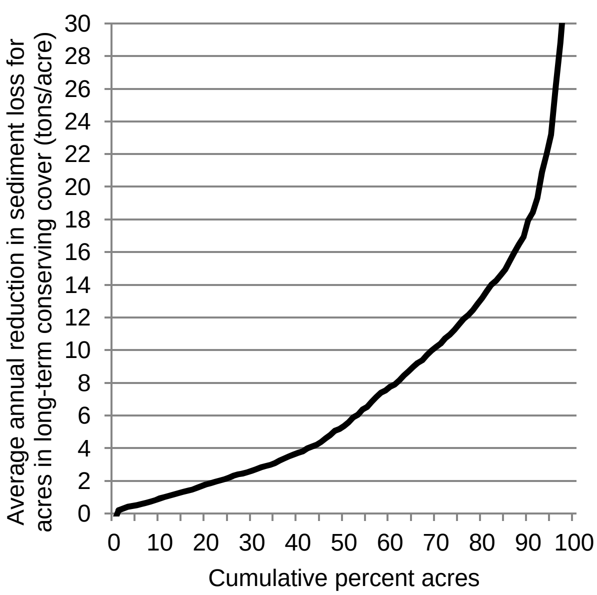
		Average annual sediment loss (tons/acre)			
Conservation treatment	Percent of cropped acres	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
No-till or mulch till with carbon gain, no structural practices	40	0.59	1.13	0.54	48
No-till or mulch till with carbon loss, no structural practices	17	3.30	4.57	1.26	28
Some crops with reduced tillage, no structural practices	2	1.98	2.89	0.91	31
Structural practices and no-till or mulch till with carbon gain	23	0.59	2.77	2.17	79
Structural practices and no-till or mulch till with carbon loss	13	3.34	8.04	4.70	58
Structural practices and some crops with reduced tillage	1	2.76	7.95	5.19	65
Structural practices only	2	3.13	6.20	3.08	50
No water erosion control treatment	2	4.19	4.20	0.01	0
All acres	100	1.59	3.29	1.70	52

Note: Differences in slope, soil texture, hydrologic group, and precipitation for acres in different treatment groups account for some of the differences shown in this table. Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

Land in long-term conserving cover. Acres in long-term conserving cover have very little erosion or sediment loss, and thus show nearly 100-percent reductions when compared to a cropped condition (table 14). If these 776,400 acres were still being cropped without any conservation practices, sediment loss would average about 8 tons per acre per year for these acres.

Reductions in sediment loss for land in long-term conserving cover compared to the same acres with crops and no conservation practices vary, as shown in figure 24. About one-third of the acres in long-term conserving cover have reductions of less than 3 tons per acre per year. In contrast, reductions greater than 15 tons per acre per year occur on about 15 percent of the acres with long-term conserving cover.

Figure 24. Estimates of average annual reduction in sediment loss due to conversion to long-term conserving cover in the Ohio-Tennessee River Basin



Effects of Practices on Soil Organic Carbon

The landscape and climate in the Ohio-Tennessee River Basin is much less conducive to maintaining and enhancing soil organic carbon relative to landscapes and climate of the soils in the Upper Mississippi River Basin. The combination of higher rainfall on more sloping soils and somewhat milder winters that allow for more degradation of organic materials make carbon accumulation more challenging. The steeper soils in the Appalachian region of this basin, which developed from igneous, sedimentary, and metamorphic bedrock parent materials, tend to be more shallow and less fertile, making carbon sequestration much more challenging. Soils in the northern portions of the basin in Ohio and Indiana developed from glacial materials, some later covered by loess. These soils are very fertile and have the highest potential for storing soil carbon. Soils in the warmer, higher-rainfall southern region of the basin in Kentucky, Tennessee, and Alabama are largely loess soils developed over limestone, sandstone, or shale. The highly weathered, less reactive nature of these soils makes them less able to withstand even moderately intense tillage and maintain or enhance carbon stores relative to regions of the country such as the Upper Mississippi River Basin and the northern portions of the Ohio River Basin.

In this study, estimation of soil organic carbon change is based on beginning soil characteristics that reflect the effects of years of traditional conventional tillage practices and older, lower yielding crop varieties. These effects generally resulted in soils with organic carbon levels at or near their low steady state. Modern high-yielding crop varieties with and without the adoption of conservation tillage tend to readily improve the status of carbon in many soils, especially those with beginning stocks far less than the steady state representation of the present management. Beginning the simulations at a lower steady state for carbon allows for a more equitable comparison of conservation practices, particularly conservation tillage. Because of this, however, model estimates of soil organic carbon change may be somewhat larger than shown in other studies. Nevertheless, model estimates obtained in this study fall within the expected range for the continuum of adoption of new crop genetics and tillage practices.

Baseline condition for cropped acres

Model simulation shows that for the baseline conservation condition the average annual soil organic carbon change is a gain of about 27 pounds per acre per year, on average (table 16), with about 66 percent of the acres gaining annually in soil organic carbon and 34 percent of cropped acres losing soil organic carbon, on average. These estimates account for losses of carbon with sediment removed from the field by wind and water erosion. Loss of soil organic carbon due to wind and water erosion averages about 258 pounds per acre per year for the baseline conservation condition (table 16).

Cropped acres that are gaining soil organic carbon every year provide soil quality benefits that enhance production and reduce the potential for sediment, nutrient, and pesticide losses. Soil organic carbon improves the soil's ability to function with respect to nutrient cycling, improves water holding capacity, and reduces erodibility. However, enhancement of carbon stores in parts of this region on a scale seen in other Midwestern basins could only occur with significant shifts in crop mixes toward rotations with cover crops, hay or pasture as components.

Given the challenging nature of the inherent conditions in parts of this region, maintenance of soil organic carbon is also an important benchmark. Cropping systems can be considered to be maintaining soil organic carbon if average annual losses do not exceed 100 pounds per acre per year; this rate of change is typically too small to detect via typical soil sampling over a 20-year period. Applying this criterion, about 20 percent of the acres in the region would be considered to be maintaining (but not enhancing) soil organic carbon. When combined with acres enhancing soil organic carbon, a total of 86 percent of the acres in the region would be either maintaining or enhancing soil organic carbon (fig. 25).

Effects of conservation practices on cropped acres

Without conservation practices, the annual change in soil organic carbon would be an average loss of 5 pounds per acre per year, compared to an average gain of 27 pounds per acre for the baseline (table 16). Thus, conservation practices in the region have resulted in an average annual gain in soil organic carbon of 32 pounds per acre per year on cropped acres.

However, average annual change in soil organic carbon varies considerably among acres in the region, as shown in figure 25. For the baseline conservation condition, the 66 percent of acres gaining soil organic carbon have an average annual gain of 104 pounds per acre per year. If conservation practices were not in use, only 57 percent of the acres would be gaining soil organic carbon and the annual rate of gain would be about 91 pounds per acre per year on those acres.

The average annual gain in soil organic carbon due to practices varies among acres, as shown in figure 26, depending on the extent to which residue and nutrient management is used, as well as the soil's potential to sequester carbon.

Some of the increased gain in soil organic carbon due to conservation practices is the result of soil erosion control—keeping soil organic carbon on the field promotes soil quality. Residues are not only key in increasing soil organic carbon, they are also vital as physical protection against erosion losses. The trend in carbon lost to wind and water would appear to not support the benefits of conservation practices with an average loss of 248 pounds per acre per year without practices compared to 258 pounds per acre with conservation practices (table 16). However, this is simply a result of more reside on the surface available for loss in the baseline condition. The net gain in soil organic carbon for the baseline is a good indicator that sufficient residues are present for sequestration and soil protection. The added tillage of the no practice scenario increases losses due to oxidation and therefore lowers the amounts available for wind and water losses. The unique trend observed in this region is a result of its transitional climate from the cooler and drier Midwest to the warmer, more humid east and southeast.

For air quality concerns, the analysis centers on the decrease in carbon dioxide emissions. Soils gaining carbon are obviously diminishing emissions, but so are soils that continue to lose carbon but at a slower rate. For all cropped acres, the gain in soil organic carbon of 32 pounds per acre due to conservation practice use is equivalent to a carbon dixide emission reduction of 1.5 million U.S. tons of carbon dioxide for the Ohio-Tennessee River Basin.

Table 16. Field-level effects of conservation practices on soil organic carbon for cultivated cropland in the Ohio-Tennessee River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (25.0 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	258	248	-10	-4%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	27	-5	32*	--
Land in long-term conserving cover (0.8 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	167	452	286	63%
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	390	-107	497*	--

* Gain in soil organic carbon due to conservation practices.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 18 subregions.

Figure 25. Estimates of average annual change in soil organic carbon for cropped acres in the Ohio-Tennessee River Basin

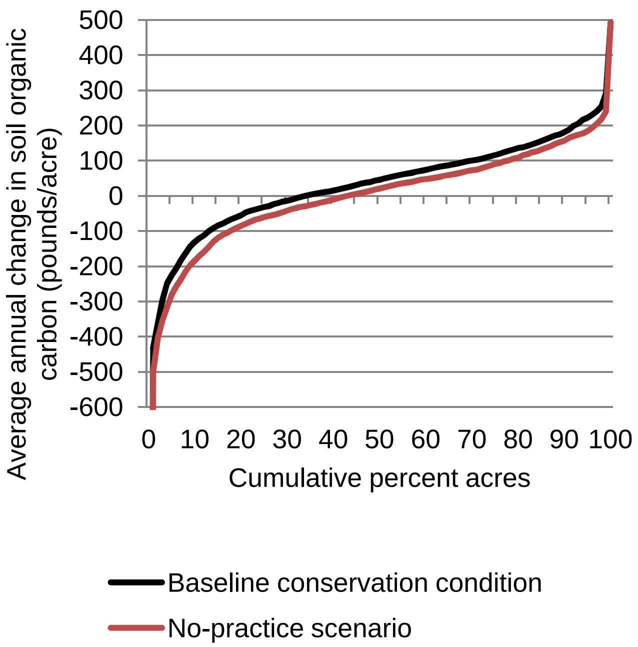
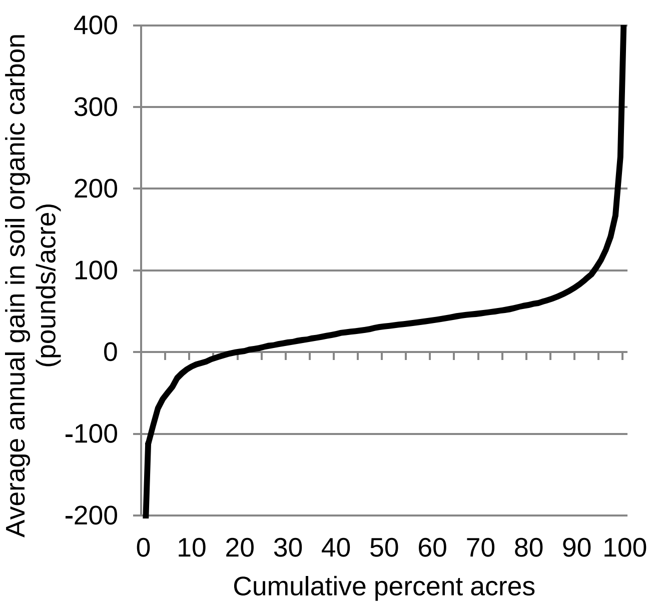


Figure 26. Estimates of average annual gain in soil organic carbon due to the use of conservation practices on cropped acres in the Ohio-Tennessee River Basin



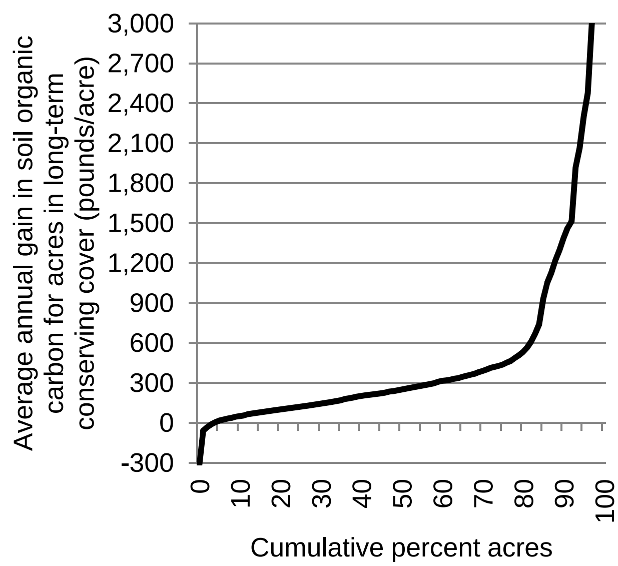
Note: About 19 percent of the acres have a higher soil organic carbon increase in the no-practice scenario than the baseline conservation condition because of the higher fertilization rates, including manure application rates, used in the no-practice scenario to simulate the effects of nutrient management practices.

Land in long-term conserving cover

For land in long-term conserving cover, the annual change in soil organic carbon for the baseline conservation condition averages 390 pounds per acre per year (table 16). If these acres were still being cropped without any conservation practices, the annual average change in soil organic carbon would be a loss of 107 pounds per acre per year.

For these 766,400 acres, the gain in soil organic carbon averages 497 pounds per acre compared to a cropped condition without conservation practices. This is equivalent to a carbon dioxide emission reduction of 0.7 million U.S. tons of carbon dioxide for the region. However, the rate of emission reduction due to conservation practices varies considerably among acres in long-term conserving cover, as indicated by the wide range of average annual gains in soil organic carbon shown in figure 27.

Figure 27. Estimates of average annual gain in soil organic carbon due to conversion to long-term conserving cover in the Ohio-Tennessee River Basin



Note: About 3 percent of the acres in long-term conserving cover have decreases in annual carbon gain compared to a cropped condition. Biomass production under long-term conserving cover is typically nitrogen limited. The higher biomass production and resulting crop residue from the fertilization of cropped acres can exceed the carbon benefits of long-term conserving cover under some conditions.

Effects of Practices on Nitrogen Loss

Plant-available nitrogen sources include application of commercial fertilizer, application of manure, nitrogen produced by legume crops (soybeans, alfalfa, dry beans, and peas), a small amount of manure deposited by grazing livestock, and atmospheric nitrogen deposition. In total, these sources provide about 156 pounds of nitrogen per acre per year for cropped acres in the Ohio-Tennessee River Basin (table 17). Model simulations show that about 73 percent of this (114 pounds per acre) is taken up by the crop and removed at harvest in the crop yield, on average, and the remainder is lost from the field through various pathways.

Baseline condition for cropped acres

For the baseline conservation condition, the annual average amount of total nitrogen lost from the field, other than the nitrogen removed from the field at harvest, is about 42.6 pounds per acre. These nitrogen loss pathways are (fig. 28 and table 17)—

- nitrogen lost due to volatilization associated primarily with fertilizer and manure application (average of 7.5 pounds per acre per year);
- nitrogen returned to the atmosphere through denitrification (average of 2.5 pounds per acre per year);
- nitrogen lost with windborne sediment (average of 0.2 pounds per acre per year);
- nitrogen lost with surface runoff (average of 13.2 pounds per acre per year), most of which is nitrogen lost with waterborne sediment; and
- nitrogen loss in subsurface flow pathways (average of 19.2 pounds per acre per year).

The two pathways that impact water quality directly—surface water *and* subsurface flows (average of 32.4 pounds/acre per year) —account for 76 percent of the total nitrogen loss in this region. Most of the nitrogen loss in subsurface flows returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Model simulation results showed that nitrogen loss to specific pathways varies from acre to acre, as shown in figures 29 and 30. However, loss of nitrogen in subsurface flows is the dominant loss pathway for 68 percent of the cropped acres in the region. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) Nitrogen loss with waterborne sediment is the dominant loss pathway for 21 percent of the cropped acres, and nitrogen lost through volatilization is the dominant loss pathway for 9 percent of cropped acres. The remaining loss pathways were dominant for only 2 percent of the acres in this region.

Loss of nitrogen in subsurface flows can be quite high for some acres (fig. 29). Average annual losses of nitrogen in subsurface flows exceed 50 pounds per acre per year for the 5 percent of acres with the highest losses.

Acres receiving manure (9 percent of cropped acres) have higher nitrogen loss than acres not receiving manure. Total nitrogen loss for acres receiving manure was 66 pounds per acre per year, compared to 40 pounds per acre per year for acres not receiving manure (table 17). Total nitrogen losses were also higher for highly erodible acres (27 percent of cropped acres) compared to non-highly erodible acres. Total nitrogen loss for highly erodible acres is 55 pounds per acre per year, compared to 38 pounds per acre per year for non-highly erodible acres (table 17).

Figure 28. Average annual nitrogen loss by loss pathway, Ohio-Tennessee River Basin, baseline conservation condition

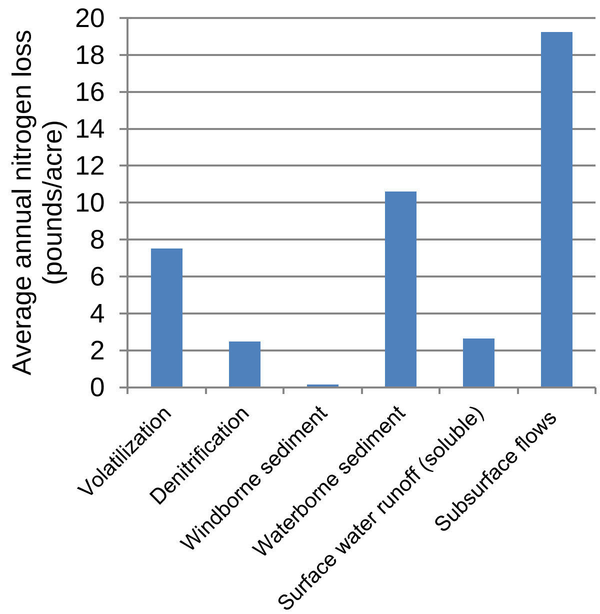


Figure 29. Cumulative distributions of average annual nitrogen lost through various loss pathways, Ohio-Tennessee River Basin, baseline conservation condition

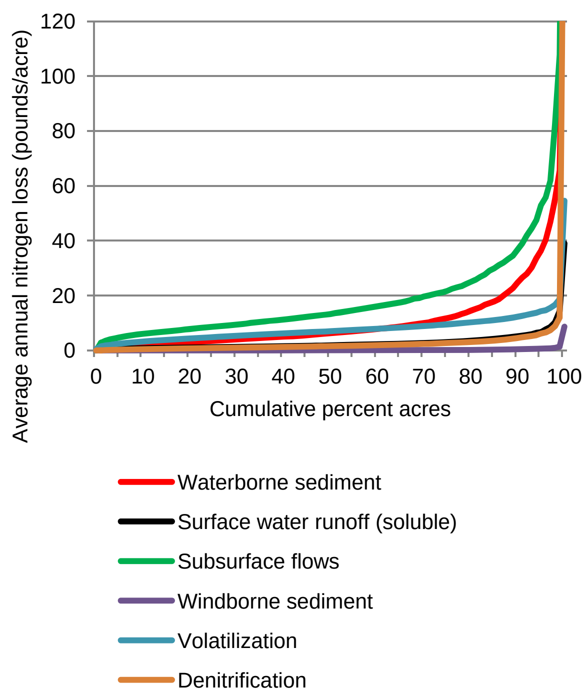
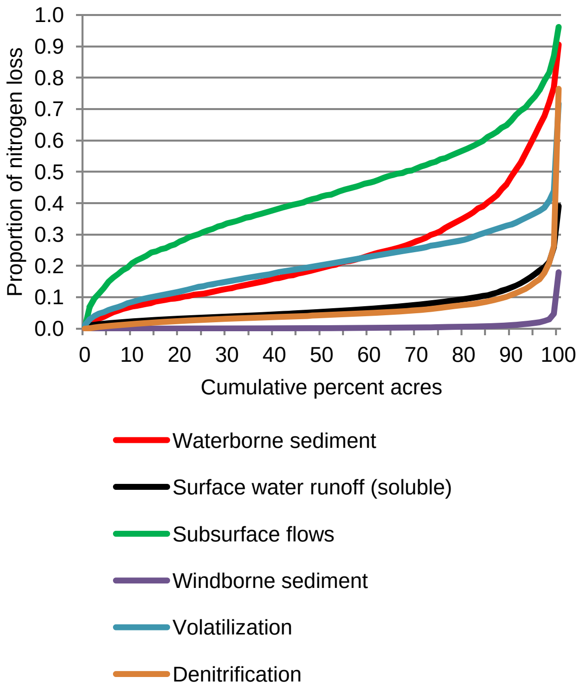


Figure 30. Cumulative distributions of proportions of nitrogen lost through six loss pathways, Ohio-Tennessee River Basin



Note: The horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same acres on another curve.

Model simulations for the baseline conservation condition indicate that some cropped acres in the Ohio-Tennessee River Basin are much more susceptible to the effects of weather than other acres and lose much higher amounts of nitrogen (fig. 31). About 40 percent of the acres lose less than 40 pounds per acre per year through the various loss pathways under *all* weather conditions. About 15 percent of the acres, on the other hand, lose more than 100 pounds per acre in at least some years, and lose more than 40 pounds per acre in almost every year. In years with the most extreme weather, up to 5 percent of the acres lose over 150 pounds of nitrogen. Figure 31 also shows that nitrogen loss for the 30 percent of the cropped acres with the highest losses varies significantly from year to year when compared to the 30 percent with the lowest total nitrogen loss.

The *average annual* total nitrogen loss for the baseline is shown in figure 32. Acres with the highest nitrogen losses have the highest inherent vulnerability combined with inadequate nutrient management and runoff controls. About 59 percent of cropped acres lose less than 40 pounds per acre per year, while 4 percent lose more than 100 pounds per acre per year.

Table 17. Field-level effects of conservation practices on nitrogen sources and nitrogen loss pathways for cropped acres in the Ohio-Tennessee River Basin

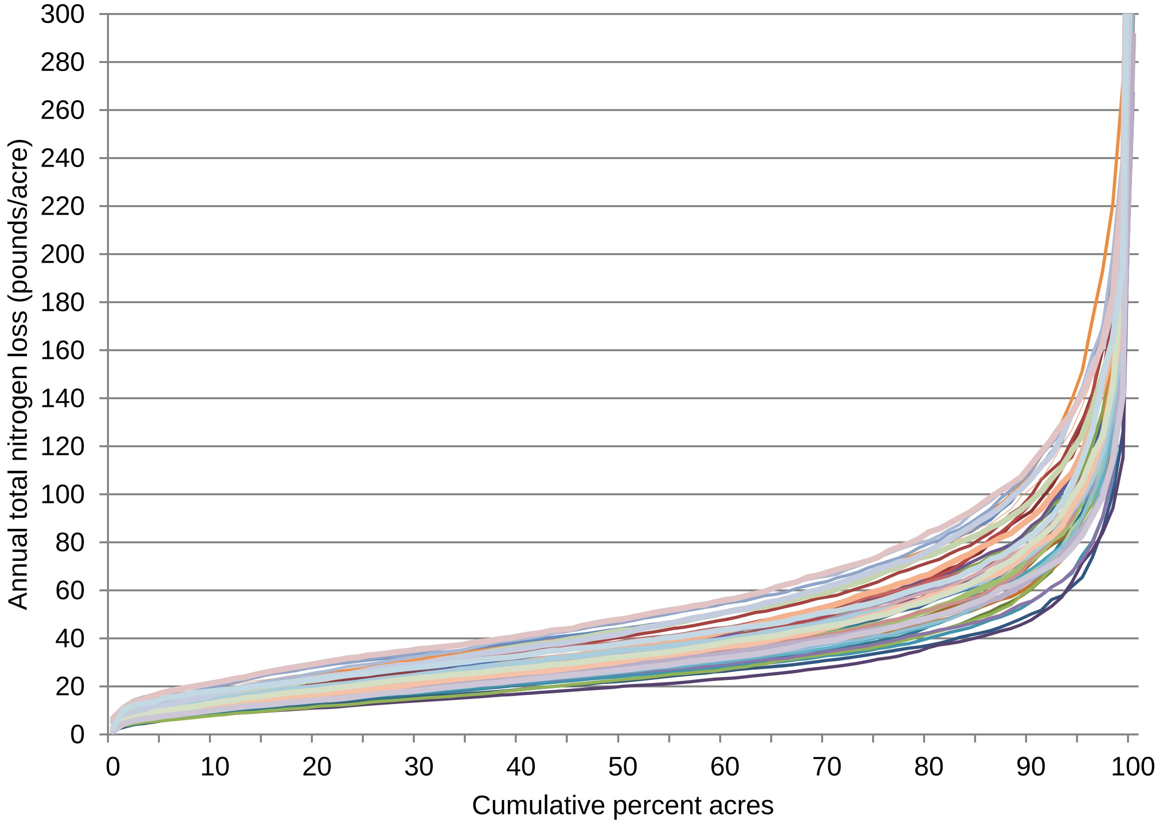
Model simulated outcome	Average annual values in pounds per acre: Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
All cropped acres				
Nitrogen sources				
Atmospheric deposition	8.4	8.4	0.0	0
Bio-fixation by legumes	64.3	62.2	-2.1	-3
Nitrogen applied as commercial fertilizer and manure	83.8	98.3	14.5	15
All nitrogen sources	156.5	169.0	12.5	7
Nitrogen in crop yield removed at harvest	114.2	121.0	6.8*	6*
Nitrogen loss pathways				
Nitrogen loss by volatilization	7.5	6.2	-1.3**	-21**
Nitrogen loss through denitrification	2.5	2.5	0.0**	0**
Nitrogen lost with windborne sediment	0.2	0.3	0.1	47
Nitrogen loss with surface runoff, including waterborne sediment	13.2	20.5	7.3	35
Nitrogen loss with surface water (soluble)	2.6	6.8	4.2	61
Nitrogen loss with waterborne sediment	10.6	13.7	3.1	22
Nitrogen loss in subsurface flow pathways	19.2	21.6	2.3	11
Total nitrogen loss for all loss pathways	42.6	51.1	8.4	17
Change in soil nitrogen	-1.8	-3.9	-2.2	--
Highly erodible land (27 percent of cropped acres)				
All nitrogen sources	155.4	168.9	13.5	8
Total nitrogen loss for all loss pathways	54.8	68.1	13.3	19
Non-highly erodible land (73 percent of cropped acres)				
All nitrogen sources	156.9	169.0	12.1	7
Total nitrogen loss for all loss pathways	38.2	44.9	6.7	15
Acres with manure applied (9 percent of cropped acres)				
All nitrogen sources	178.8	201.4	22.6	11
Total nitrogen loss for all loss pathways	66.2	85.1	18.9	22
Acres without manure applied (91 percent of cropped acres)				
All nitrogen sources	154.4	165.9	11.5	7
Total nitrogen loss for all loss pathways	40.4	47.9	7.5	16

* The reduction in yield reflects the increase in nutrients in the representation in the no-practice scenario for nutrient management.

****** On over half of the cropped acres, more nitrogen volatilization and denitrification occurs with practices than without practices, resulting in only a small change in nitrogen volatilization and denitrification on average for the region due to conservation practices. In preventing nitrogen loss to other loss pathways, conservation practices keep more of the nitrogen compounds on the field longer, where it is exposed to wind and weather conditions that promote volatilization and denitrification.

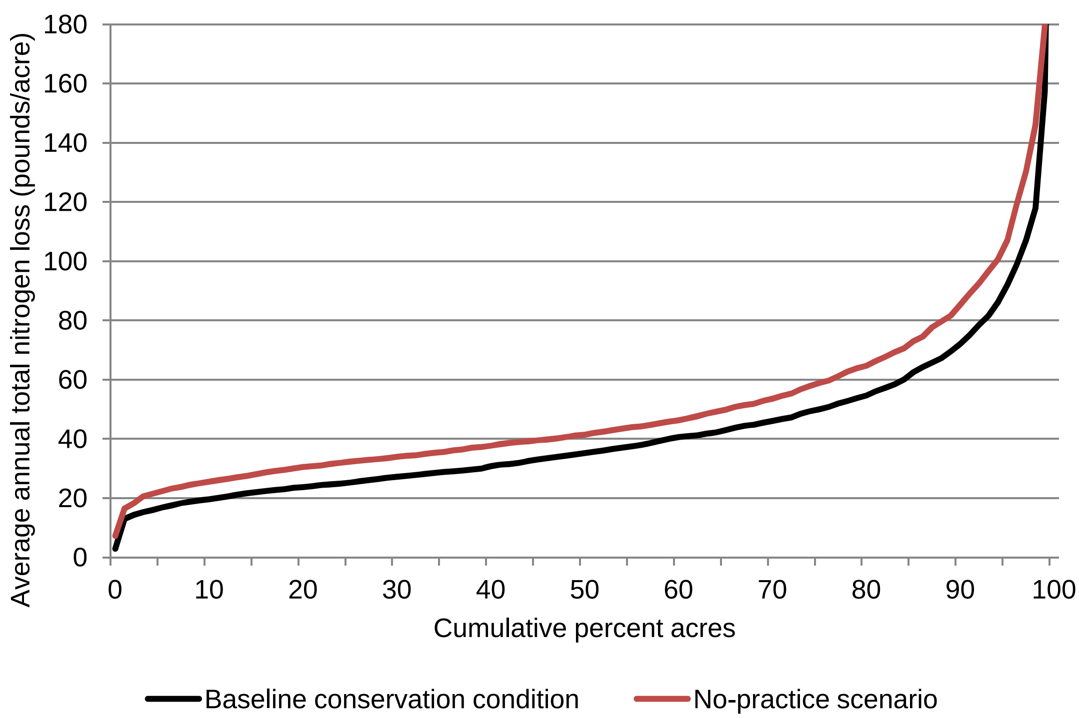
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 18 subregions.

Figure 31. Distribution of annual total nitrogen loss for each year of the 47-year model simulation, Ohio-Tennessee River Basin



Note: This figure shows how annual total nitrogen loss (pounds per acre per year) varied within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total nitrogen loss varied over the region in that year, starting with the acres with the lowest total nitrogen loss and increasing to the acres with the highest total nitrogen loss. The family of curves shows how annual total nitrogen loss varied from year to year. The average annual curve for the baseline is shown in figure 32 (below).

Figure 32. Estimates of average annual total nitrogen loss for cropped acres in the Ohio-Tennessee River Basin

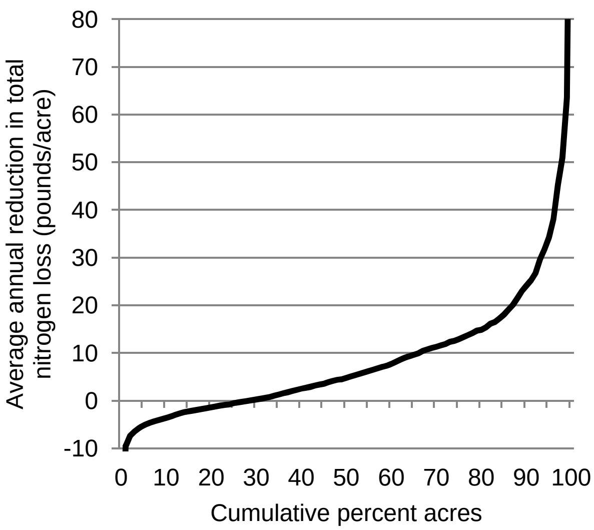


Effects of conservation practices on cropped acres
Model simulations show that the conservation practices in use in the region have reduced total nitrogen loss from cropped acres by an average of 8 pounds per acre per year, representing a 17 percent reduction, on average (table 17). Without conservation practices, about 53 percent of the cropped acres would have average annual total nitrogen loss exceeding 40 pounds per acre per year; with conservation practices, 41 percent of acres exceed this level of loss (fig. 32).

The effects of conservation practices vary from acre to acre (fig. 33). About half of the acres have average annual reductions in total nitrogen loss below 5 pounds per acre. In contrast, about 13 percent of the acres have reduced total nitrogen loss by an average of over 20 pounds per acre per year. These are acres with higher levels of treatment and often higher levels of nitrogen use in the no-practice scenario.

Figure 33 also shows that about 28 percent of the acres have an *increase* in total nitrogen loss due to conservation practice use. Most of these increases are small; only 7 percent of the acres have increases of more than 4 pounds per acre. This result primarily occurs on soils with relatively high soil nitrogen content and generally with low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. Cropping systems that include legumes can have a higher soil nitrogen stock in the baseline conditions because legumes produce proportionately less biofixation of nitrogen under the higher fertilization rates simulated in the no-practice scenario.

Figure 33. Estimates of average annual reduction in total nitrogen loss due to the use of conservation practices on cropped acres in the Ohio-Tennessee River Basin



Note: See text for discussion of conditions that result in lower total nitrogen loss in the no-practice scenario than in the baseline conservation condition for 28 percent of the acres.

Nitrogen lost with surface runoff. Model simulations show that, on average, nitrogen lost with surface runoff has been reduced 35 percent due to use of conservation practices in the region (table 17). Without conservation practices, about 50 percent of the cropped acres would have nitrogen lost with surface runoff in excess of an average of 15 pounds per acre per year, compared to only 25 percent of the acres in the baseline conservation condition (fig. 34). Figure 35 shows that about 20 percent of the cropped acres have reductions in nitrogen lost with surface runoff greater than 10 pounds per acre due to conservation practice use. Figure 35 also shows, however, that about 47 percent of the acres have reductions less than 5 pounds per acre due to conservation practices.

Figure 34. Estimates of average annual nitrogen lost with surface runoff (including waterborne sediment) for cropped acres in the Ohio-Tennessee River Basin

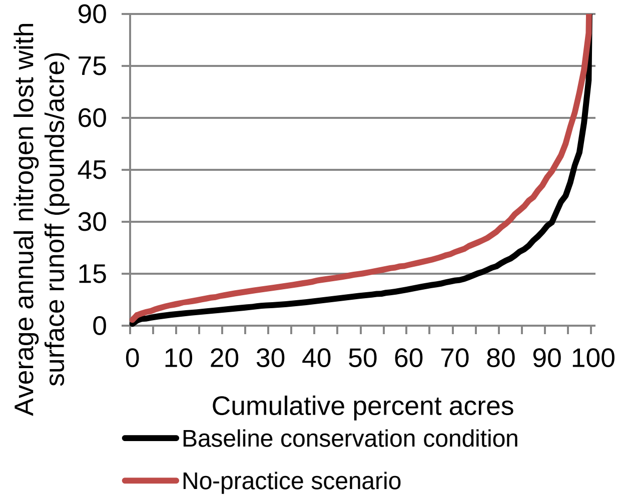
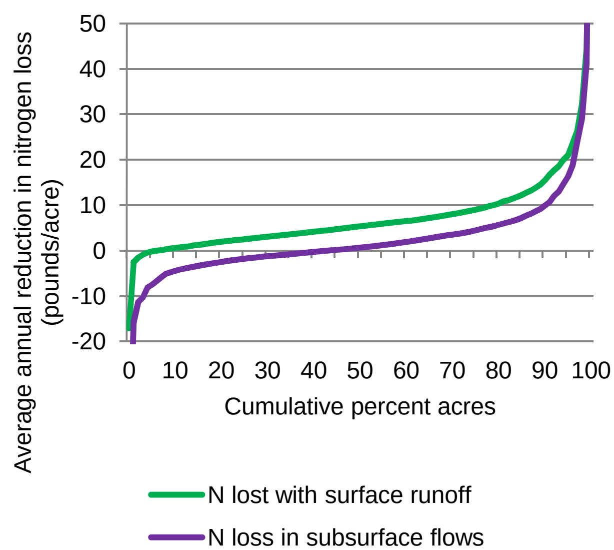


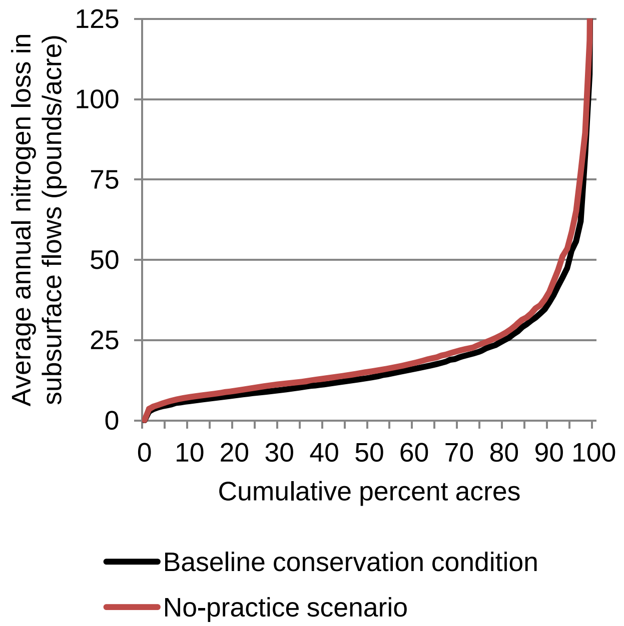
Figure 35. Estimates of average annual reduction in nitrogen lost with surface runoff and reduction in nitrogen loss in subsurface flows due to the use of conservation practices on cropped acres in the Ohio-Tennessee River Basin



Note: See text for discussion of negative reductions for loss of nitrogen in subsurface flows.

Nitrogen loss in subsurface flows. Conservation practices are effective in reducing nitrogen loss in subsurface flows on some acres in this region, but make little difference on most acres and even result in increases in nitrogen loss in subsurface flows for 42 percent of cropped acres (figs. 35 and 36). (Increases in nitrogen loss in subsurface flows are represented in figure 35 as negative reductions.) On average, conservation practices have reduced nitrogen loss in subsurface flows from 21.6 pounds per acre without practices to only 19.2 pounds per acre with practices, representing an average reduction of only 2.3 pounds per acre per year (11-percent reduction) (table 17). Figure 35 shows that reductions in average annual nitrogen loss in subsurface flows exceed 10 pounds per acre for only 10 percent of the cropped acres, and are less than 1 pound per acre for about half of the acres.

Figure 36. Estimates of average annual nitrogen loss in subsurface flows for cropped acres in the Ohio-Tennessee River Basin



The increases in nitrogen loss in subsurface flows due to conservation practices on 42 percent of the cropped acres (fig. 35) are largely due to relatively weak nutrient management practices on acres with erosion control treatment. A portion of the reduction in nitrogen lost with surface runoff is re-routed to subsurface loss pathways, resulting in gains or only small reductions in nitrogen loss in subsurface flows. This re-routing of surface water runoff to subsurface flow pathways results in additional nitrogen being leached from the soil, diminishing and sometimes offsetting the overall positive effects of conservation practices on total nitrogen loss.

These model simulation results underscore the importance of pairing water erosion control practices with effective nutrient management practices so that the full suite of conservation practices will provide the environmental protection needed.

Tradeoffs in Conservation Treatment

Conservation practices applied on cropland are, for the most part, synergistic. The benefits accumulate as more practices are added to the designed systems. However, when only a single resource concern is addressed (such as soil erosion), antagonism between the practices and other resource concerns may occur. That is why it is essential that all resource concerns be considered during the conservation planning process. Most of the time the tradeoffs are much smaller than the magnitude of the primary resource concerns. Common examples are:

- Terraces and conservation tillage are planned to solve a serious water erosion problem. However, in some areas there may be concern about seeps at the lower part of the field. The planned practices will solve the erosion problem, but could exacerbate the seep problem under some conditions. Ignoring that fact does not make for an adequate conservation plan.
- Conservation tillage is planned for erosion control on a cropland field with a high water table. The reduction in runoff may increase leaching of nitrates into the shallow water table. This potential secondary problem requires additional nutrient management practices to address the concern.
- A nutrient management plan reduces the amount of manure added to a field to reduce the loss of nutrients to surface or groundwater. However, the reduction in organic material added to the field may reduce the soil organic matter or reduce the rate of change in soil organic matter.
- Figure 33 shows that about 28 percent of the acres have an increase in total nitrogen loss due to conservation practice use. This result occurs primarily on soils with relatively high soil nitrogen content and generally low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. For these fields, the nutrient management component of a farmer's conservation plan would need to be enhanced to reduce or eliminate the negative effects of soil erosion control practices on nitrogen loss.

A *comprehensive planning process* is used to identify the appropriate combination of practices needed to address multiple resource concerns by taking into account the specific inherent vulnerabilities associated with each field. To ensure that proper consideration is given to the effects of conservation practices on *all* of the resource concerns, USDA/NRCS developed a comprehensive planning tool referred to as CPPE (Conservation Practice Physical Effects). The CPPE is included in the Field Office Technical Guide. Conservation planners are expected to use CPPE as a reference to ensure that *all* resource concerns are addressed in conservation plans.

Land in long-term conserving cover

Total nitrogen loss has been reduced by about 80 percent on the 0.8 million acres in long-term conserving cover, compared to conditions that would be expected had the acres remained in crops. Converting cropped acres to long-term conserving cover is very effective in reducing total nitrogen loss, as demonstrated in figure 37 and table 18, although the reductions are much higher for some acres than others. Conversion of cropped acres to long-term conserving cover in the region has reduced total nitrogen loss from these acres by an average loss of 66 pounds per acre per year to about 13 pounds per acre per year, a reduction of 53 pounds per acre per year.

Conversion of cropped acres to long-term conserving cover has also reduced nitrogen lost with surface runoff from these acres from an average loss of 35.4 pounds per acre per year to about 2.7 pounds per acre per year, a reduction of 33 pounds per acre. Subsurface losses have been reduced from 20.1 pounds per acre per year to an average of 1.7 pounds per acre, a reduction of 18.4 pounds per acre per year.

Figure 37. Estimates of average annual total nitrogen loss for land in long-term conserving cover in the Ohio-Tennessee River Basin

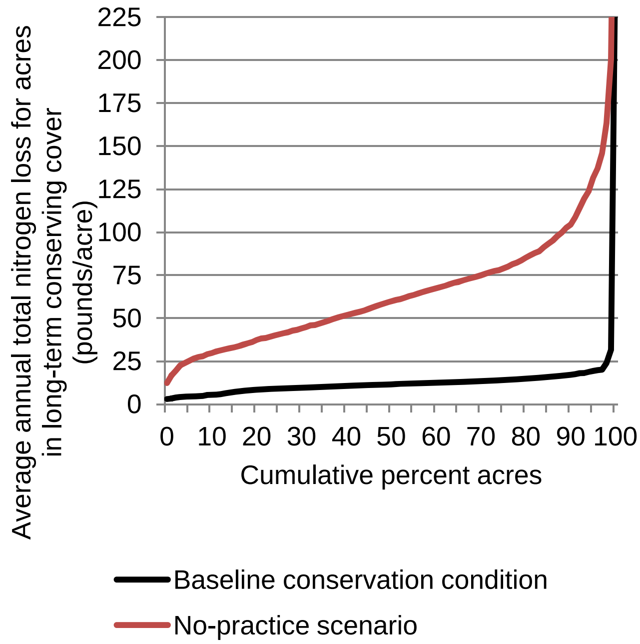


Table 18. Effects of conservation practices on nitrogen sources and nitrogen loss pathways for land in long-term conserving cover (0.8 million acres), Ohio-Tennessee River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
Nitrogen sources				
Atmospheric deposition	8.1	8.1	0.0	0
Bio-fixation by legumes	11.7	58.2	46.5	80
Nitrogen applied as commercial fertilizer and manure	0.0	98.2	98.2	100
All nitrogen sources	19.8	164.4	144.7	88
Nitrogen in crop yield removed at harvest	0.4*	110.6	110.2	100
Nitrogen loss pathways				
Nitrogen loss by volatilization	6.78	6.41	-0.36	-6
Nitrogen loss through denitrification	2.18	4.14	1.95	47
Nitrogen lost with windborne sediment	0.00	0.03	0.03	100
Nitrogen loss with surface runoff, including waterborne sediment	2.67	35.43	32.76	92
Nitrogen loss with surface water (soluble)	0.64	7.52	6.88	92
Nitrogen loss with waterborne sediment	2.03	27.91	25.88	93
Nitrogen loss in subsurface flow pathways	1.73	20.11	18.38	91
Total nitrogen loss for all pathways	13.36	66.11	52.76	80
Change in soil nitrogen	5.57	-12.94	-18.51	--

* Harvest was simulated on acres planted to trees where expected tree age is less than the 47 years included in the model simulation. At tree harvest time, the grass also is removed and replanted.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Effects of Practices on Phosphorus Loss

Phosphorus, like nitrogen, is an essential element needed for crop growth. Unlike nitrogen, phosphorus rarely occurs in a gaseous form so the agricultural model has no atmospheric component. Phosphorus compounds that are soluble in water are available for plants to use. Although total phosphorus is plentiful in the soil, only a small fraction is available at any one time for plant uptake. Farmers apply commercial phosphate fertilizers to supplement low quantities of plant-available phosphorus in the soil.

Throughout this report, phosphorus results are reported in terms of elemental phosphorus (i.e., not as the phosphate fertilizer equivalent).

Baseline condition for cropped acres

In the model simulations for the Ohio-Tennessee River Basin, about 24 pounds per acre of phosphorus were applied as commercial fertilizer or in manure to cropped acres, on average, in each year of the model simulation (table 19). About 73 percent of the phosphorus applied is taken up by the crop and removed at harvest—18 pounds per acre per year, on average.

Total phosphorus loss for all loss pathways averaged 4.58 pounds per acre per year in the baseline conservation condition (table 19). These phosphorus loss pathways are—

- phosphorus lost with windborne sediment (average of 0.04 pound per acre per year);
- phosphorus lost with waterborne sediment (average of 2.14 pound per acre per year);
- soluble phosphorus lost to surface water, including soluble phosphorus in surface water runoff, and soluble phosphorus that infiltrates into the soil profile but quickly returns to surface water either through quick return lateral flow or intercepted by drainage systems (average of 2.38 pounds per acre per year); and
- soluble phosphorus that percolates through the soil profile into the groundwater (average of 0.03 pound per acre per year).

On average, approximately equal amounts of phosphorus are lost through the two principal loss pathways in the Ohio-Tennessee River Basin— soluble phosphorus lost to surface water (52 percent of total loss, on average) and attached to soil particles in waterborne sediment (47 percent, on average) (fig. 38, table 19). A very small amount of soluble phosphorus is lost through percolation into groundwater and with windborne sediment in this region. The percentage of phosphorus lost in each of the principal loss pathways varies from acre to acre, as shown in figure 39 for cropped acres.

Soluble phosphorus loss with surface water runoff and lateral flow (including discharge to drainage tiles, ditches, and seeps) was the dominant loss pathway for 57 percent of cropped acres. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.)

Phosphorus lost with waterborne sediment is the dominant loss pathway for 43 percent of cropped acres.

As shown previously for nitrogen, phosphorus losses are much higher for acres receiving manure (7.0 pounds per acre on average) than for acres that did not receive manure (4.4 pounds per acre on average) (table 19). This difference is directly related to the amount of phosphorus applied, which was much higher for acres receiving manure than for acres not receiving manure. Phosphorus losses are nearly twice as high for highly erodible land as for non-highly erodible land.

About 40 percent of the acres lose less than 4 pounds per acre per year through the various loss pathways under *all* weather conditions (figs. 40 and 41). In contrast, 35 percent of the acres lose more than 8 pounds per acre in at least some years. Phosphorus loses can exceed 16 pounds per acre in some years for more than 10 percent of cropped acres.

Figure 38. Estimates of average annual phosphorus lost through various loss pathways, Ohio-Tennessee River Basin, baseline conservation condition

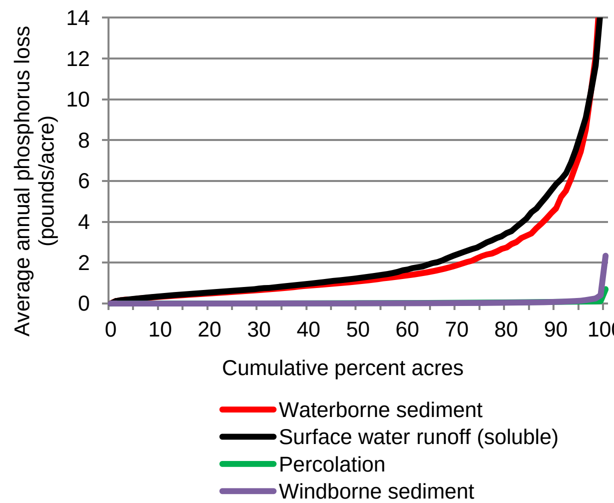


Figure 39. Cumulative distributions of the proportion of phosphorus lost through various loss pathways, Ohio-Tennessee River Basin, baseline conservation condition

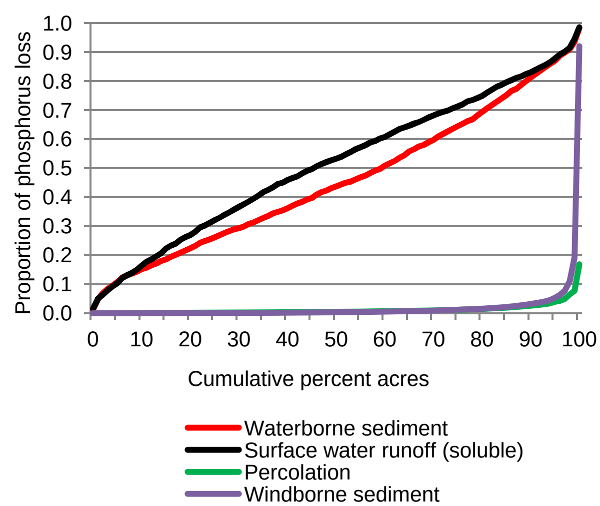
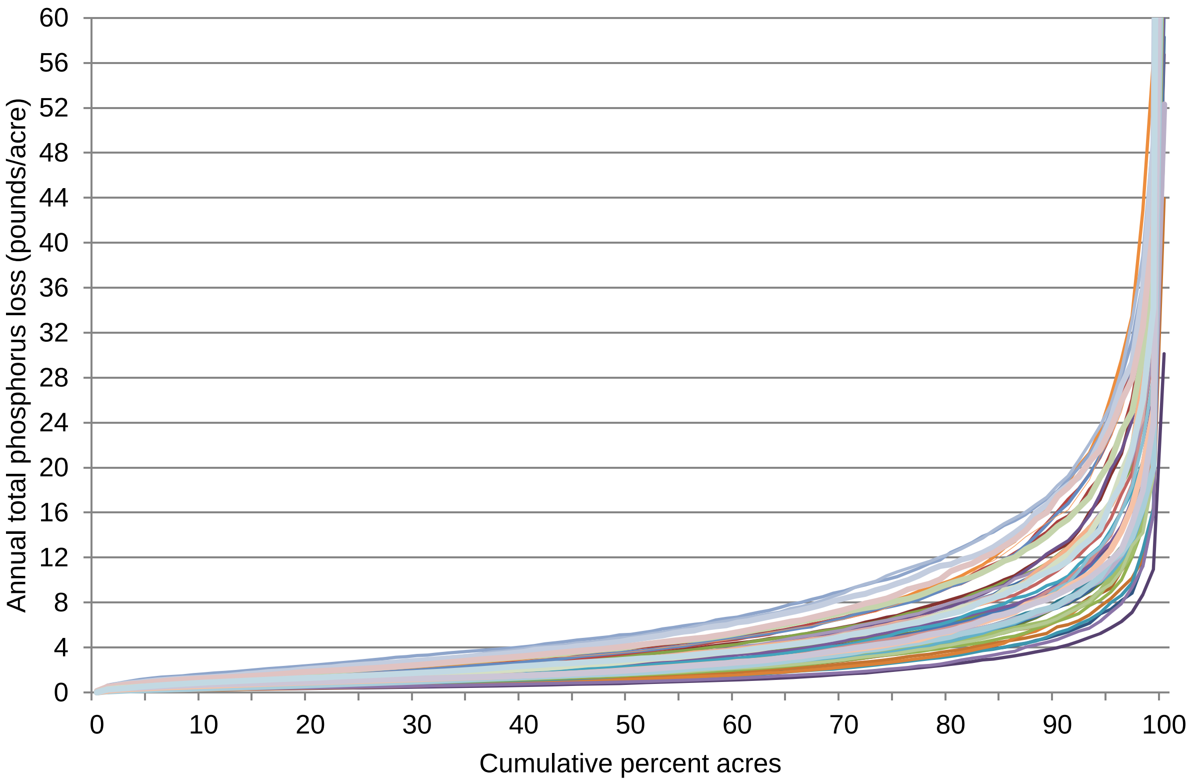


Table 19. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for cultivated cropland in the Ohio-Tennessee River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
Cropped acres (25.0 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	24.4	31.3	6.9	22
Phosphorus in crop yield removed at harvest	17.93	18.91	0.98	5
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.04	0.10	0.06	63
Phosphorus lost to surface water (sediment attached and soluble)*	4.52	6.75	2.23	33
Soluble phosphorus lost to surface water*	2.38	3.10	0.72	23
Phosphorus loss with waterborne sediment	2.14	3.65	1.51	41
Soluble phosphorus loss to groundwater	0.03	0.03	0.00	0
Total phosphorus loss for all loss pathways	4.58	6.88	2.30	33
Change in soil phosphorus	1.68	5.43	3.75	--
Highly erodible land (27 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	25.6	30.6	5.0	16
Total phosphorus loss for all loss pathways	7.0	9.9	2.85	29
Non-highly erodible land (73 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	24.0	31.6	7.6	24
Total phosphorus loss for all loss pathways	3.7	5.8	2.10	36
Acres with manure applied (9 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	34.4	41.2	6.8	17
Total phosphorus loss for all loss pathways	7.0	9.9	2.89	29
Acres without manure applied (91 percent of cropped acres)				
Phosphorus applied as commercial fertilizer	23.5	30.4	6.9	23
Total phosphorus loss for all loss pathways	4.4	6.6	2.24	34
Land in long-term conserving cover (0.8 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.00	29.70	29.70	100
Phosphorus in crop yield removed at harvest	0.23**	17.21	16.99	99
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.00	0.01	0.01	100
Phosphorus lost to surface water (sediment attached and soluble)*	0.63	10.14	9.51	94
Soluble phosphorus lost to surface water*	0.43	2.97	2.55	86
Phosphorus loss with waterborne sediment	0.21	7.17	6.96	97
Soluble phosphorus loss to groundwater	0.09	0.04	-0.05	-105
Total phosphorus loss for all loss pathways	0.72	10.19	9.47	93
Change in soil phosphorus	-1.14	1.85	2.99	--

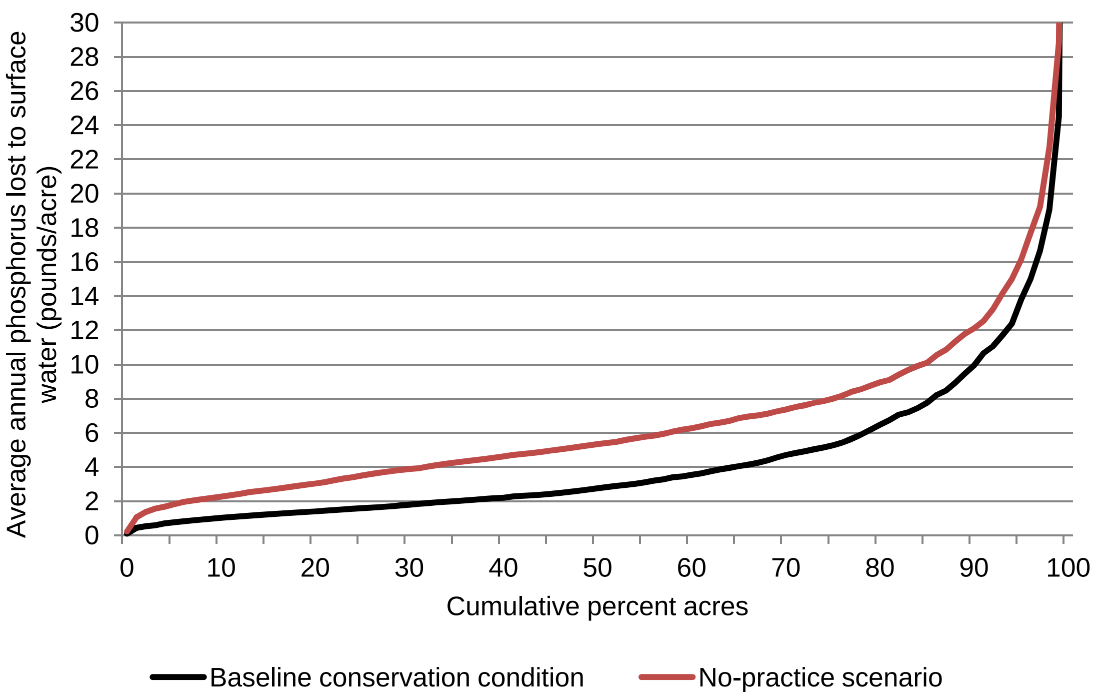
* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.
** Harvest was simulated on acres planted to trees where expected tree age is less than the 47 years included in the model simulation. At tree harvest time, the grass also is removed and replanted.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 18 subregions.

Figure 40. Distribution of annual total phosphorus loss for each year of the 47-year model simulation, Ohio-Tennessee River Basin



Note: This figure shows how annual total phosphorus loss (pounds per acre per year) varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total phosphorus loss varied over the region in that year, starting with the acres with the lowest total phosphorus loss and increasing to the acres with the highest total phosphorus loss. The family of curves shows how annual total phosphorus loss varied from year to year.

Figure 41. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for cropped acres in the Ohio-Tennessee River Basin



* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Effects of conservation practices on cropped acres

Conservation practices have reduced total phosphorus lost to surface water for cropped acres by 33 percent, reducing the average loss from 6.88 pounds per acre per year if conservation practices were not in use to 4.58 pounds per acre per year for the baseline conservation condition (table 19). On average, conservation practices have reduced phosphorus loss with waterborne sediment by 41 percent, whereas soluble phosphorus lost to surface water has been reduced only 23 percent (table 19).

The effects of conservation practices on phosphorus lost to surface water (soluble and sediment attached) are shown in figures 41 and 42 for cropped acres. With the conservation practices in use as represented by the baseline conservation condition, about 35 percent of cropped acres exceed 4 pounds per acre per year, on average. Without those practices in use, phosphorus lost to surface water would exceed 4 pounds per acre for 68 percent of the acres (fig. 41).

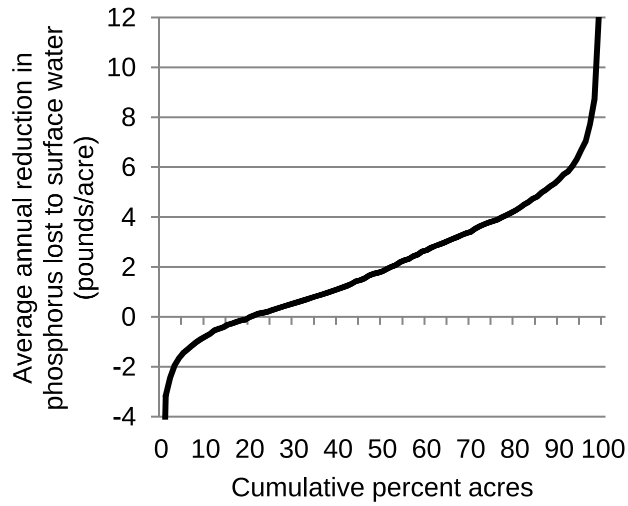
The effects of conservation practices on phosphorus lost to surface water vary considerably throughout the Ohio-Tennessee River Basin, as shown in figure 42. At the high end, reductions exceed 4 pounds per acre for about 22 percent of the acres. These are acres with higher levels of treatment and often higher levels of phosphorus use in the no-practice scenario.

For about 20 percent of the acres, however, conservation practice use results in *increases* in phosphorus lost to surface water. (Increases in phosphorus lost to surface water are represented in figure 42 as negative reductions.) This phenomenon is a result of a combination of practices and landscape conditions. Nearly all of these acres (94 percent) had the lowest ratings for phosphorus management and 90 percent had one or more crop in the rotation with a phosphorus application that was not incorporated. In addition, nearly all the soils were on nearly level slopes and not at high risk for sediment loss or phosphorus lost with waterborne sediment. These conditions cause phosphorus levels to concentrate near or on the soil surface, where it is more vulnerable to surface runoff. Soluble phosphorus loss was the dominant loss pathway for most of these acres. Because phosphorus management was generally poor, the only change simulated in the no-practice scenario for most of these acres was to reverse the reduced tillage by adding two diskings in the spring. This additional tillage incorporated the phosphorus, which reduced soluble phosphorus loss to levels below those in the baseline. On these types of landscapes, improved phosphorus management along with light incorporation and maintenance of crop residue on the soil surface is necessary to reduce soluble phosphorus loss.[18]

Land in long-term conserving cover

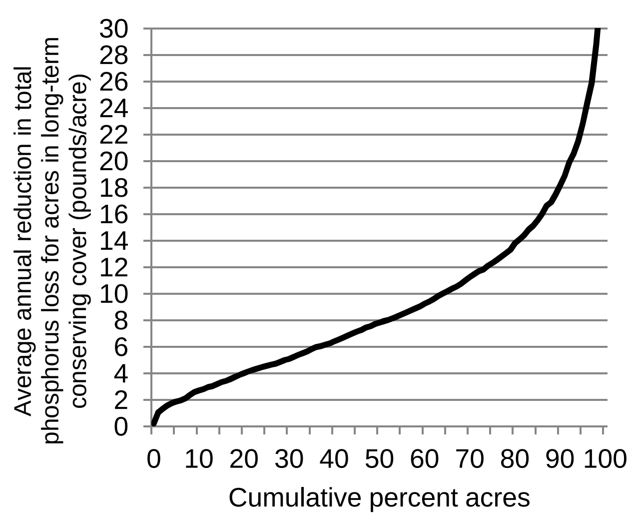
For land in long-term conserving cover, total phosphorus loss is 93 percent less than it would have been if crops had been grown and no conservation practices used, reducing total phosphorus loss by 9.5 pounds per acre per year, on average (table 19 and figure 43). Reductions range from less than 3 pounds per acre for the 10 percent of acres with the lowest reductions to over 18 pounds per acre per year for the acres with the highest reductions.

Figure 42. Estimates of average annual reduction in phosphorus lost to surface water (sediment attached and soluble) due to conservation practices on cropped acres in the Ohio-Tennessee River Basin



Note: Acres with negative reductions in phosphorus loss due to conservation practices were on nearly level soils and soluble phosphorus was the primary loss pathway. In these cases, the additional tillage in the no practice scenario significantly reduced the loss of soluble phosphorus. See text.

Figure 43. Estimates of average annual reduction in total phosphorus loss due to conversion to long-term conserving cover in the Ohio-Tennessee River Basin



[18] The additional treatment scenarios presented in chapter 6 showed that these negative reductions due to conservation tillage practices do not occur in the presence of good phosphorus management (appropriate rate, timing, and method of application).

Effects of Practices on Pesticide Residues and Environmental Risk

Use of pesticides to protect crops from weeds, insects, and diseases is an integral part of crop production. While pesticides are essential for large-scale agriculture, pesticide residues can migrate from the application site and lead to unintentional risk to humans and non-target plants and animals. Most pesticides are applied at much lower rates than nutrients. The fraction of pesticides applied that migrates offsite with water is generally less than 1 to 2 percent. Nevertheless, small amounts of pesticide residue can create water quality concerns depending on the toxicity of the pesticide residues to non-target species and even exceed EPA drinking water standards at times.

Baseline condition for pesticide loss

The APEX model tracks the mass loss of pesticides dissolved in surface water runoff, adsorbed to sediment lost through water erosion, and dissolved in subsurface flow pathways.[19] The distribution of losses through each of these three pathways is contrasted in figure 44. All three pathways are important in the transport of pesticide residues from fields, but the majority of pesticide loss is dissolved in surface water runoff, on average. Pesticides dissolved in surface water runoff accounted for 63 percent of the total mass loss, waterborne sediment accounted for about 21 percent, and pesticides in subsurface flows accounted for 15 percent.

The dominant loss pathway for 66 percent of cropped acres was pesticides dissolved in surface water runoff. Waterborne sediment was the dominant pesticide loss pathway for 23 percent of the acres, and subsurface flows were the dominant pesticide loss pathway for 8 percent of the acres. The remaining 3 percent of the acres had no pesticide loss.

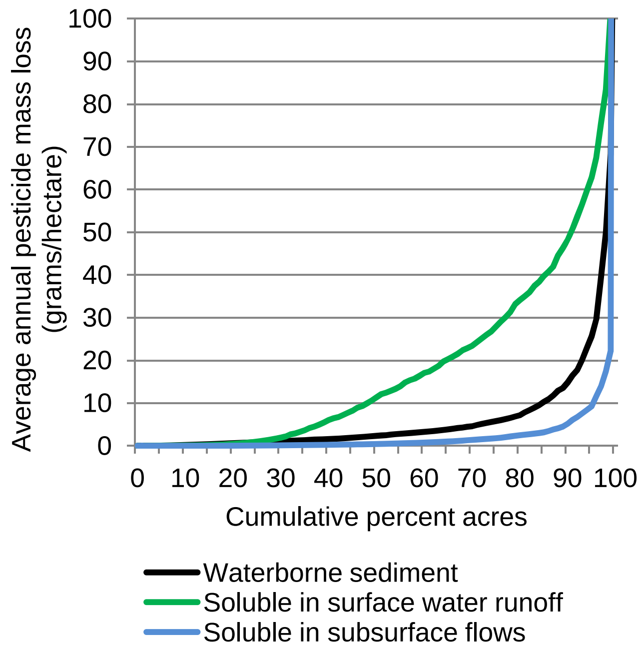
The average annual amount of pesticide lost from farm fields in the Ohio-Tennessee River Basin is about 28 grams of active ingredient per hectare per year (table 20).[20] As was observed for sediment and nutrient loss, the majority of pesticide loss occurs on a minority of acres within the Ohio-Tennessee River Basin (fig. 44). The median loss is only 18.4 grams per hectare.

In the model simulations, the pesticide applied in the largest amount throughout the region was glyphosate at 32 percent of the total weight of pesticides applied, followed closely by atrazine at 27 percent (table 21). The herbicides acetochlor and S-metolachlor represented 11 and 8 percent, respectively, of the total weight of pesticides applied. These four pesticides accounted for 78 percent of the pesticides applied in the region, by weight.

The most common pesticide residues lost from farm fields are atrazine (43 percent of total mass loss), S-metolachlor (10 percent), and acetochlor (9 percent), and glyphosate (9 percent) (table 21). Metolachlor, simazine, paraquat dichloride, and sulfentrazone each represent 3 to 6 percent of the total mass loss. These eight pesticides account for 88 percent of all pesticide residues lost from fields in the model simulations for the Ohio-Tennessee River Basin.

Pesticide loss for land in long-term conserving cover was not simulated because the survey did not provide information on pesticide use on land enrolled in CRP General Signups. It was assumed that there were no pesticide residues lost from land in long-term conserving cover.

Figure 44. Estimates of average annual pesticide loss (mass loss of all pesticides combined) for three loss pathways, Ohio-Tennessee River Basin, baseline conservation condition



[19] The APEX model currently does not estimate pesticides lost in spray drift or volatilization.

[20] Grams per hectare is the standard reporting unit for pesticide active ingredients.

Table 20. Field-level effects of conservation practices on pesticide loss and associated edge-of-field environmental risk for cropped acres in the Ohio-Tennessee River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Pesticide sources				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1827	2091	264	13
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	27.5	34.1	6.5	19
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	4.36	6.10	1.75	29
Average annual surface water pesticide risk indicator for humans	0.93	1.15	0.22	19
Average annual groundwater pesticide risk indicator for humans	0.16	0.19	0.03	15

Note: It was assumed that no pesticides were applied to land in long-term conserving cover and there were no data on residual pesticides in the soil for these acres; thus, the assessment of the effects of this practice on pesticide loss was not done.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 18 subregions.

Table 21. Dominant pesticides applied in model simulations and contributing to losses, Ohio-Tennessee River Basin

Pesticide (active ingredient name)	Pesticide type	Percent of total applied in the region
Pesticide application*		
Glyphosate, isopropylamine salt	Herbicide	32
Atrazine	Herbicide	27
Acetochlor	Herbicide	11
S-Metolachlor	Herbicide	8
Metolachlor	Herbicide	4
Simazine	Herbicide	2
Pendimethalin	Herbicide	1
2,4-D, 2-ethylhexyl ester	Herbicide	1
Chlorpyrifos	Insecticide	1
Glyphosate-trimesium	Herbicide	<1
Glyphosate	Herbicide	<1
Alachlor	Herbicide	<1
Paraquat dichloride	Herbicide	<1
Total		90
		Percent of total pesticide loss in the region**
Pesticide loss from farm fields*		
Atrazine	Herbicide	43
S-Metolachlor	Herbicide	10
Acetochlor	Herbicide	9
Glyphosate, isopropylamine salt	Herbicide	9
Metolachlor	Herbicide	6
Simazine	Herbicide	4
Paraquat dichloride	Herbicide	4
Sulfentrazone	Herbicide	3
Pendimethalin	Herbicide	1
2,4-D 2-ethylhexyl ester	Herbicide	1
Sodium chlorate	Herbicide	1
Total		92

* Pesticides not listed each represented less than 1 percent of the total. Percents may not add to total due to rounding.
** Includes loss of pesticides dissolved in surface water runoff, adsorbed to sediment loss from water erosion, and dissolved in subsurface flow pathways.

Effects of conservation practices on pesticide residues and risk

Management practices that reduce the potential for loss of pesticides from farm fields consist of a combination of Integrated Pest Management (IPM) techniques and water erosion control practices. Water erosion control practices mitigate the loss of pesticides from farm fields by reducing surface water runoff and sediment loss, both of which carry pesticide residues from the farm field to the surrounding environment. IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environmental condition. IPM consists of a management strategy for prevention, avoidance, monitoring, and suppression of pest populations. When the use of pesticides is necessary to protect crop yields, selection of pesticides that have the least environmental risk is an important aspect of the suppression component of IPM.

Model simulations show that conservation practices—primarily water erosion control practices—are effective in reducing the loss of pesticide residues from farm fields. Use of conservation practices has reduced the loss of pesticides (summed over all pesticides) by an average of 6.5 grams of active ingredient per hectare per year, a 19-percent reduction from the 34.1 grams per hectare for the no-practice scenario (table 20).

However, the total quantity of pesticide residues lost from the field is not the most useful outcome measure for assessing the environmental benefits of conservation practices. The environmental impact is specific to the toxicity of each pesticide to non-target species that may be exposed to the pesticide.

Pesticide risk indicators were therefore developed to represent risk at the edge of the field (bottom of soil profile for groundwater). These edge-of-field risk indicators are based on the ratio of pesticide concentrations in water leaving the field to safe concentrations (toxicity thresholds) for each pesticide. As such, these risk indicators do not have units. The pesticide risk indicators were developed so that the relative risk for individual pesticides could be aggregated over the 158 pesticides included in the model for the Ohio-Tennessee River Basin.[21]

Risk indicator values of less than 1 are considered "safe" because the concentration is below the toxicity threshold for exposure at the edge of the field.[22]

Three edge-of-field risk indicators are used here to assess the effects of conservation practices: (1) surface water pesticide risk indicator for aquatic ecosystems, (2) surface water pesticide risk indicator for humans, and (3) groundwater pesticide risk indicator for humans. The surface water risk indicator includes pesticide residues in solution in surface water runoff and in all subsurface water flow pathways that eventually return to surface water (water flow in a surface or tile drainage system, lateral subsurface water flow, and groundwater return flow). The pesticide risk indicator for aquatic ecosystems was based on chronic toxicities for fish and invertebrates, and acute toxicities for algae and vascular aquatic plants. The pesticide risk indicators for humans were based on drinking water standards or the equivalent for pesticides where standards have not been set.

These indicators provide a consistent measure that is comparable from field to field and that represents the effects of farming activities on risk reduction without being influenced by other landscape factors. In most environmental settings, however, non-target species are exposed to concentrations that have been diluted by water from other sources, even when those environments are located adjacent to a field. Consequently, these edge-of-field risk indicators cannot be used to predict actual environmental impacts.

Atrazine was the dominant pesticide contributing to all three risk indicators (table 22). Based on the model simulations, the edge-of-field risk indicator for atrazine exceeded 1 for 54 percent of the cropped acres for risk to aquatic ecosystems, 30 percent of the cropped acres for surface water risk to humans, and 2 percent of the cropped acres for groundwater risk to humans. Atrazine's dominance in the risk indicators is due to its widespread use, its mobility (solubility = 30 mg/L; Koc = 100 g/ml), its persistence (field half-life = 60 days), its toxicity to aquatic ecosystems (aquatic plant toxicity = 1 ppb), and the human drinking water standard (EPA Maximum Contaminant Level = 3 ppb).

Figure 45 shows that for most years the overall risk for aquatic ecosystems is low, in part because of the conservation practices in use. But in some years the edge-of-field concentrations can be high relative to "safe" thresholds for some acres. The pesticide risk indicator for aquatic ecosystems averaged 4.36 over all years and cropped acres (table 20) for the baseline conservation condition. (The 4.36 value indicates that pesticide concentrations in water leaving cropped fields in the Ohio-Tennessee River Basin are, on average, 4.36 times the "safe" concentration for non-target plant and animal species when exposed to concentrations at the edge of the field.) The median value, however, is only 2.40 (fig. 46).

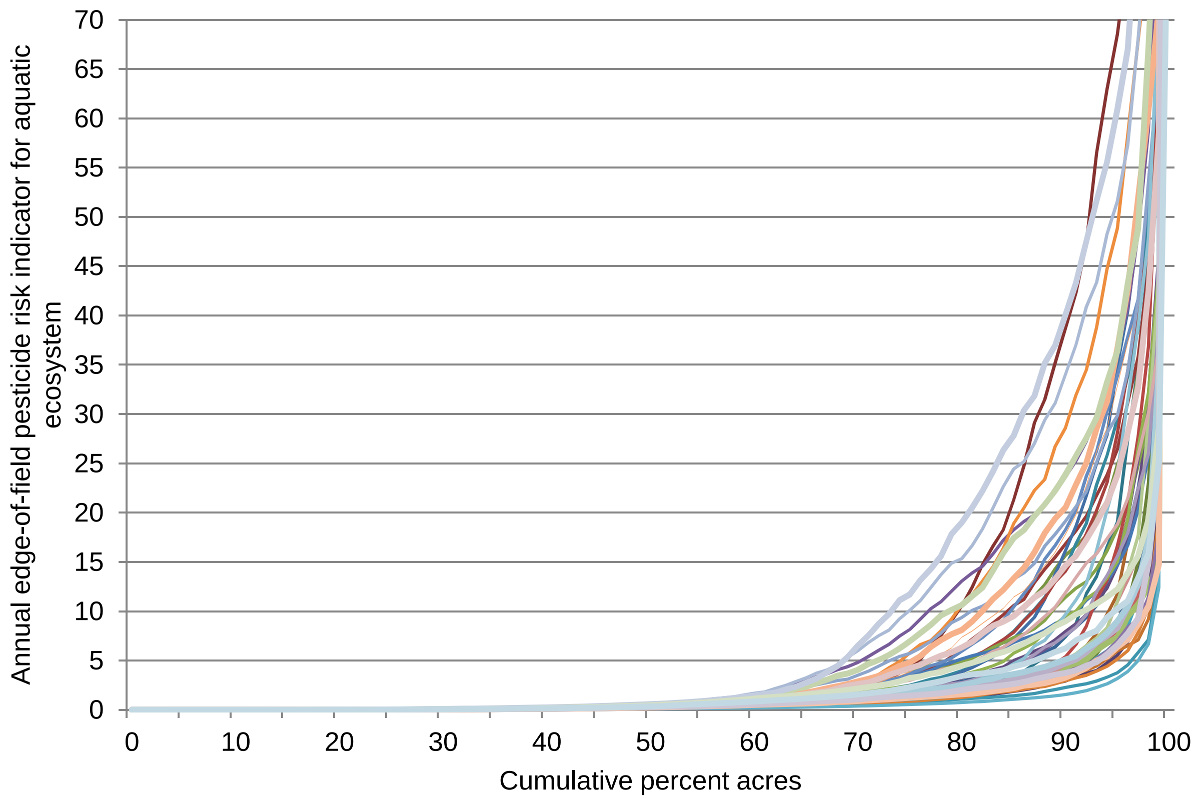
[21] For a complete documentation of the development of the pesticide risk indicators, see "Pesticide risk indicators used in the CEAP cropland modeling," found at http://www.nrcs.usda.gov/technical/nri/ceap.

[22] A threshold value of 1 for the pesticide risk indicator applies when assessing the risk for a single pesticide. Since the indicator is summed over all pesticides in this study, a threshold value of 1 would still apply if pesticide toxicities are additive and no synergistic or antagonistic effects are produced when non-target species are exposed to a mix of pesticides.

Table 22. Dominant pesticides determining edge-of-field environmental risk, Ohio-Tennessee River Basin

Pesticide (active ingredient name)	Pesticide type	Percent of cropped acres in the region with average annual edge-of-field risk indicator greater than 1
Risk indicator for aquatic ecosystem		
Atrazine	Herbicide	54
Acetochlor	Herbicide	12
Metolachlor	Herbicide	7
2,4-D, 2-ethylhexyl ester	Herbicide	6
Sulfentrazone	Herbicide	4
Phostebupirim	Insecticide	2
Chlorpyrifos	Insecticide	1
Tefluthrin	Insecticide	1
Terbufos	Insecticide	<1
Alachlor	Herbicide	<1
Risk indicator for humans, surface water		
Atrazine	Herbicide	30
Simazine	Herbicide	2
Alachlor	Herbicide	<1
Terbufos	Insecticide	<1
Risk indicator for humans, groundwater		
Atrazine	Herbicide	2
Dicrotophos	Insecticide	<1
Simazine	Herbicide	<1

Figure 45. Distribution of annual values of the edge-of-field surface water pesticide risk indicator for aquatic ecosystems for each year of the 47-year model simulation, Ohio-Tennessee River Basin



Note: This figure shows how the annual values of the risk indicator varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual values of the risk indicator varied over the region in that year, starting with the acres with the lowest value and increasing to the acres with the highest value. The family of curves shows how annual values vary from year to year.

The pesticide risk indicators for humans were much lower, averaging 0.93 for surface water and 0.16 for groundwater (table 20). The median values are 0.55 for surface water and 0.20 for groundwater. About 35 percent of the cropped acres have an average annual edge-of-field surface water pesticide risk indicator for humans greater than 1 (fig. 47).

The use of conservation practices in the Ohio-Tennessee River Basin has reduced the pesticide risk indicators by 15 to 29 percent (table 20), averaged over all years, all pesticides, and all cropped acres.

Figure 48 shows the distribution of the reductions in the two pesticide risk indicators due to conservation practices. Significant risk reductions for aquatic ecosystems occur on about 30 percent of the acres, while significant risk reductions for humans occur on only about 10 percent of the acres. The benefits of conservation practices were significant for both aquatic risks and human risks on the acres that had those risks, but aquatic risks were more widespread than human risks so conservation practices have greater total benefit for aquatic ecosystems than for human drinking water.

Figure 46. Estimates of average annual edge-of-field surface water pesticide risk indicator for aquatic ecosystem in the Ohio-Tennessee River Basin

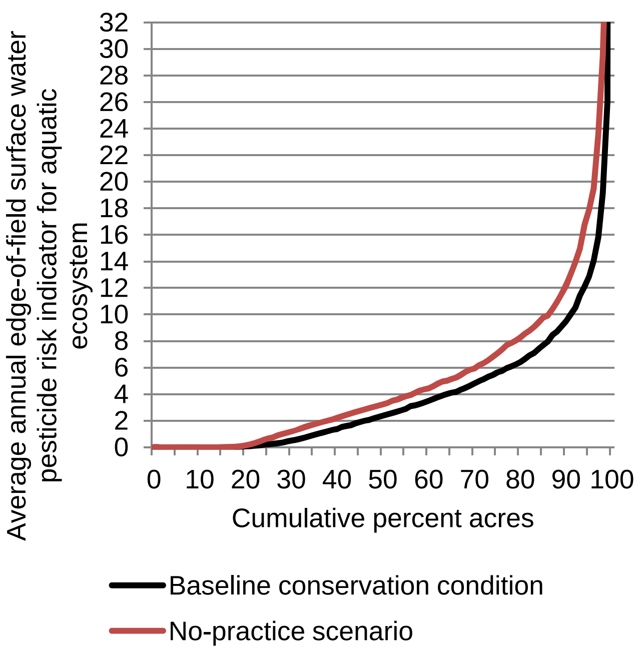


Figure 47. Estimates of average annual edge-of-field surface water pesticide risk indicator for humans in the Ohio-Tennessee River Basin

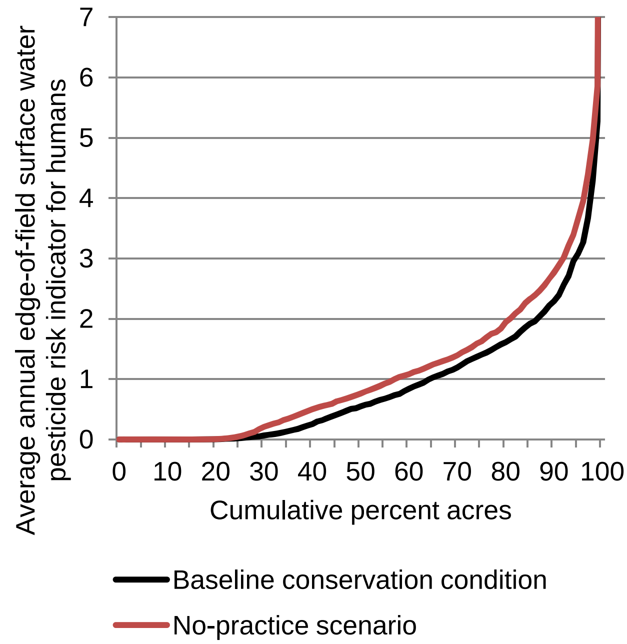
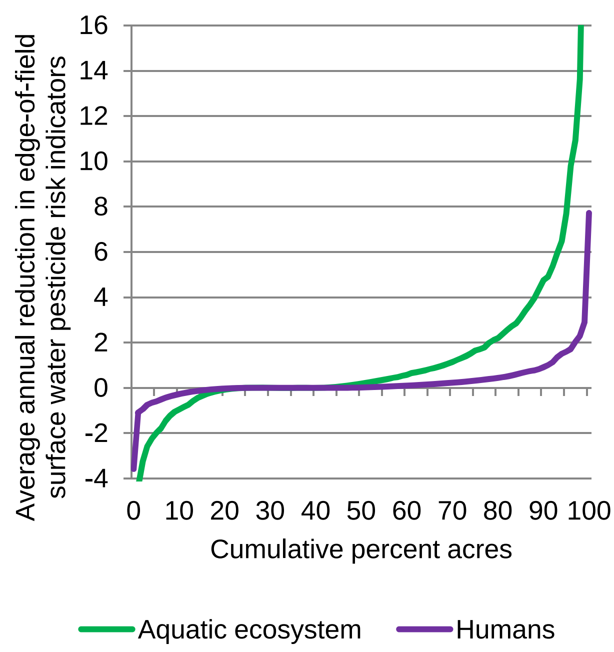


Figure 48. Estimates of average annual reductions in the edge-of-field surface water pesticide risk indicators for aquatic ecosystems in the Ohio-Tennessee River Basin



Note: Negative reductions in pesticide loss (and therefore risk) similar to negative reductions in soluble phosphorus losses occur on some landscapes as a result of reduced tillage (see discussion related to figure 42 on phosphorus reductions.)

Chapter 5
Assessment of Conservation Treatment Needs

The adequacy of conservation practices in use in the Ohio-Tennessee River Basin was evaluated to identify remaining conservation treatment needs for controlling water erosion and nutrient loss from fields. The evaluation was based on conservation practice use for the time period 2003 through 2006.

In summary, findings for the Ohio-Tennessee River Basin indicate that—

- *24 percent of cropped acres (6.0 million acres) have a **high** level of need for additional conservation treatment,*
- *46 percent of cropped acres (11.5 million acres) have a **moderate** level of need for additional conservation treatment, and*
- *30 percent of cropped acres (7.5 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.*

Field-level model simulation results for the baseline conservation conditions were used to make the assessment. Four resource concerns were evaluated for the Ohio-Tennessee River Basin:

1. Sediment loss due to water erosion
2. Nitrogen loss with surface runoff (nitrogen attached to sediment and in solution)
3. Nitrogen loss in subsurface flows
4. Phosphorus lost to surface water (phosphorus attached to sediment and in solution, including soluble phosphorus in subsurface lateral flow pathways)

The conservation treatment needs for controlling pesticide loss were not evaluated because the assessment requires information on pest infestations, which was not available for the CEAP sample points. A portion of the pesticide residues are controlled by soil erosion control practices; meeting soil erosion control treatment needs would provide partial protection against loss of pesticide residues from farm fields. Integrated Pest Management (IPM) practices are also effective in reducing the risk associated with pesticide residues leaving the farm field. Determination of adequate IPM, however, is highly dependent on the specific site conditions and the nature and extent of the pest problems.

Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field. Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres to reduce field-level losses to acceptable levels. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Under-treated acres were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Derivation of conservation treatment levels and inherent soil vulnerability classes are described in the next two sections, followed by estimates of under-treated acres.

Conservation Treatment Levels

Four levels of conservation treatment (high, moderately high, moderate, and low) were defined. A “high” level of treatment was shown by model simulations (see chapter 6) to reduce sediment and nutrient losses to low levels for nearly all cropped acres in the Ohio-Tennessee River Basin.

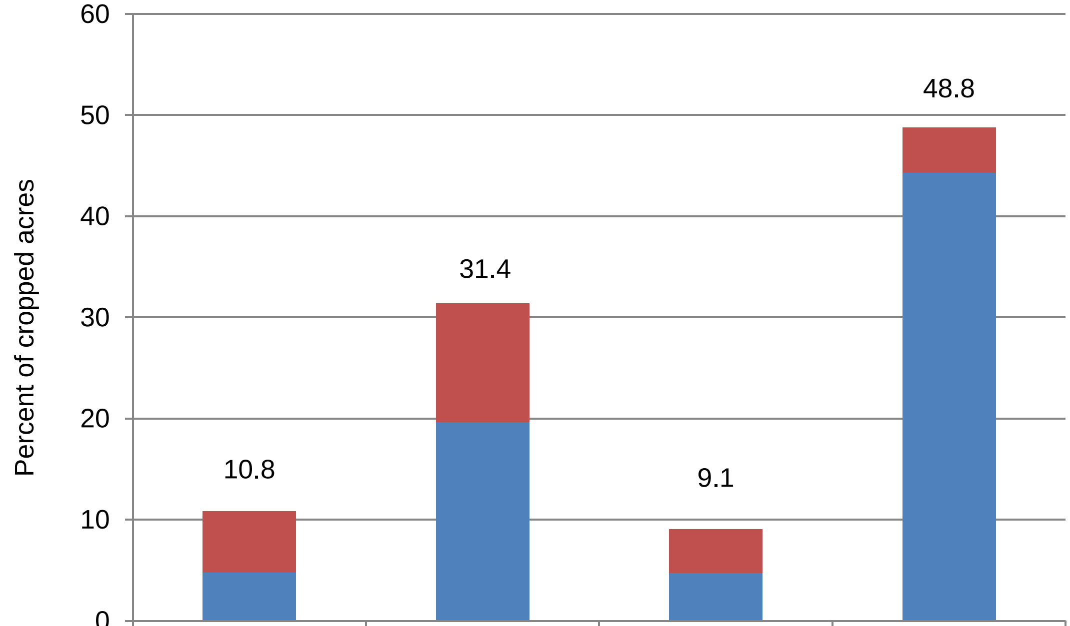
For sediment loss due to water erosion, conservation treatment levels were defined by a combination of structural practices and residue and tillage management practices, as defined in figure 49. A high level of water erosion control treatment is in use on about 49 percent of cropped acres, primarily on non-highly erodible land. About 42 percent of cropped acres have a moderate or low level of conservation treatment for water erosion control, including the majority of highly erodible land.

For nitrogen loss with surface runoff, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and nitrogen management practices, as defined in figure 50. A high level of treatment for nitrogen runoff is in use on only 6.5 percent of cropped acres. The bulk of cropped acres—86 percent--have combinations of practices that indicate a moderately high or moderate level of treatment. About 8 percent of cropped acres have a low level of treatment for nitrogen runoff.

For phosphorus lost to surface water, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and phosphorus management practices, as defined in figure 51. A high level of treatment for phosphorus runoff is in use on 10 percent of the acres. About 74 percent of cropped acres have combinations of practices that indicate a moderately high or moderate level of treatment. Only 16 percent of cropped acres have a low level of phosphorus management.

The nitrogen management level presented in figure 9 (see chapter 3) was used to evaluate the adequacy of conservation treatment for nitrogen loss in subsurface flows. A high level of treatment for nitrogen loss in subsurface flows is in use on 14 percent of the acres. About 70 percent of cropped acres have combinations of practices that indicate a moderately high or moderate level of treatment. Only 15 percent of cropped acres have a low level of nitrogen management.

Figure 49. Percent of cropped acres at four conservation treatment levels for water erosion control in the baseline conservation condition, Ohio-Tennessee River Basin



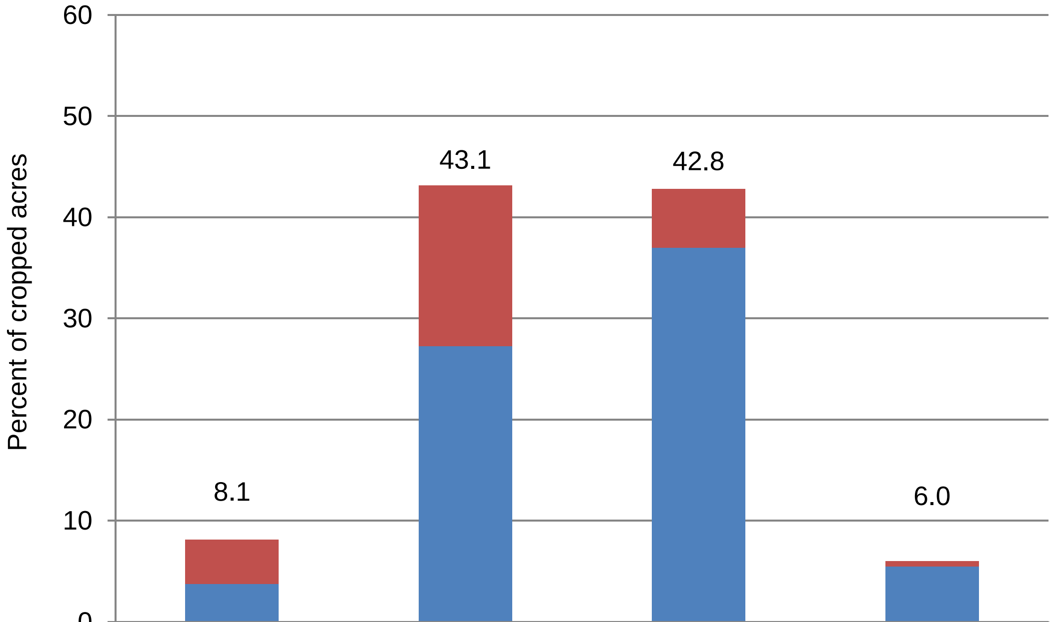
	Low	Moderate	Moderately high	High
HEL	6.0	11.7	4.4	4.5
Non-HEL	4.8	19.7	4.7	44.3

Criteria for water erosion control treatment levels were derived using a combination of structural practice treatment levels and residue and tillage management treatment levels (see figs. 7 and 8). Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1. If slope was 2 percent or less, the water erosion control treatment level is the same as the residue and tillage management level. If slope was greater than 2 percent, the water erosion control treatment level is determined as follows:

- **High treatment**: Sum of scores is equal to 8. (High treatment level for both structural practices and residue and tillage management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

Note: About 27 percent of cropped acres in the Ohio-Tennessee River Basin is highly erodible land.

Figure 50. Percent of cropped acres at four conservation treatment levels for nitrogen runoff control in the baseline conservation condition, Ohio-Tennessee River Basin



	Low	Moderate	Moderately high	High
HEL	4.4	15.9	5.8	0.5
Non-HEL	3.7	27.2	37.0	5.5

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and nitrogen management treatment levels (see figs. 7-9). Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1.

If slope was 2 percent or less, the nitrogen runoff control treatment level is determined as follows:

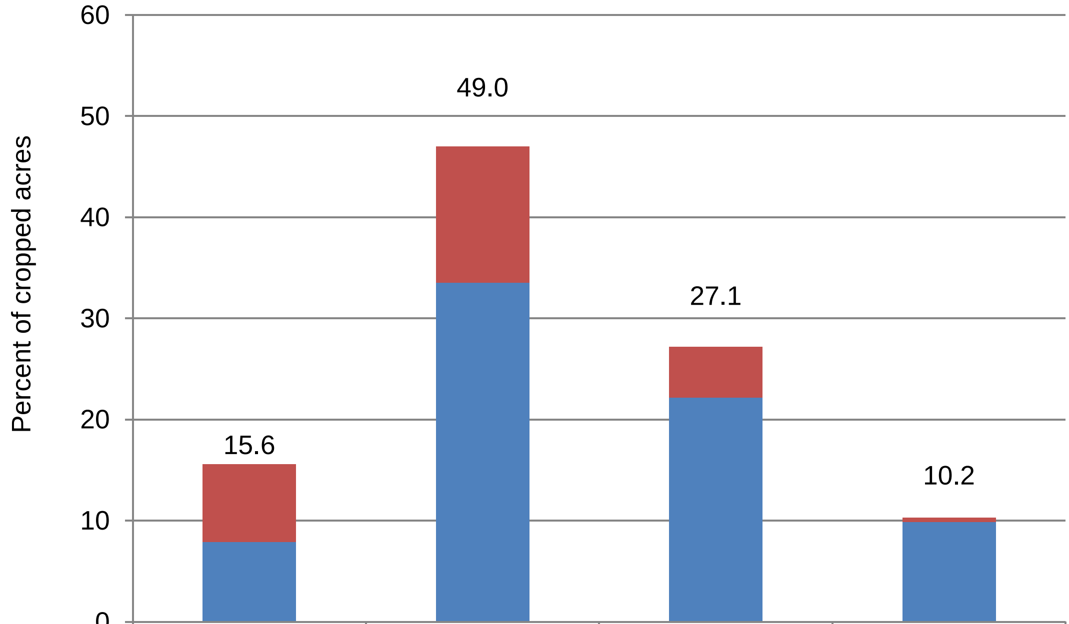
- **High treatment**: Sum of residue and tillage management score and nitrogen management score is equal to 8. (High treatment level for both structural practices and nitrogen management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the nitrogen runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and nitrogen management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 27 percent of cropped acres in the Ohio-Tennessee River Basin is highly erodible land.

Figure 51. Percent of cropped acres at four conservation treatment levels for phosphorus runoff control in the baseline conservation condition, Ohio-Tennessee River Basin



	Low	Moderate	Moderately high	High
HEL	7.7	13.5	5.0	0.4
Non-HEL	7.9	33.5	22.1	9.8

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and phosphorus management treatment levels (see figs. 7, 8, and 10) in the same manner as the nitrogen runoff control treatment level. Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1.

If slope was 2 percent or less, the phosphorus runoff control treatment level is determined as follows:

- **High treatment**: Sum of residue and tillage management score and phosphorus management score is equal to 8. (High treatment level for both structural practices and phosphorus management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the phosphorus runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and phosphorus management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 27 percent of cropped acres in the Ohio-Tennessee River Basin is highly erodible land.

Inherent Vulnerability Factors

Not all acres require the same level of conservation treatment because of differences in inherent vulnerabilities due to soils and climate. Inherent vulnerability factors for surface runoff include soil properties that promote surface water runoff and erosion—soil hydrologic group, slope , and soil erodibility (the water erosion equation K-factor). Inherent vulnerability factors for loss of nutrients in subsurface flows include soil properties that promote infiltration—soil hydrologic group, slope, water erosion equation K-factor, and coarse fragment content of the soil.

Soil runoff and leaching potentials were estimated for each sample point on the basis of vulnerability criteria. A single set of criteria was developed for all regions and soils in the United States to allow for regional comparisons. Thus, some soil vulnerability potentials are not well represented in every region.

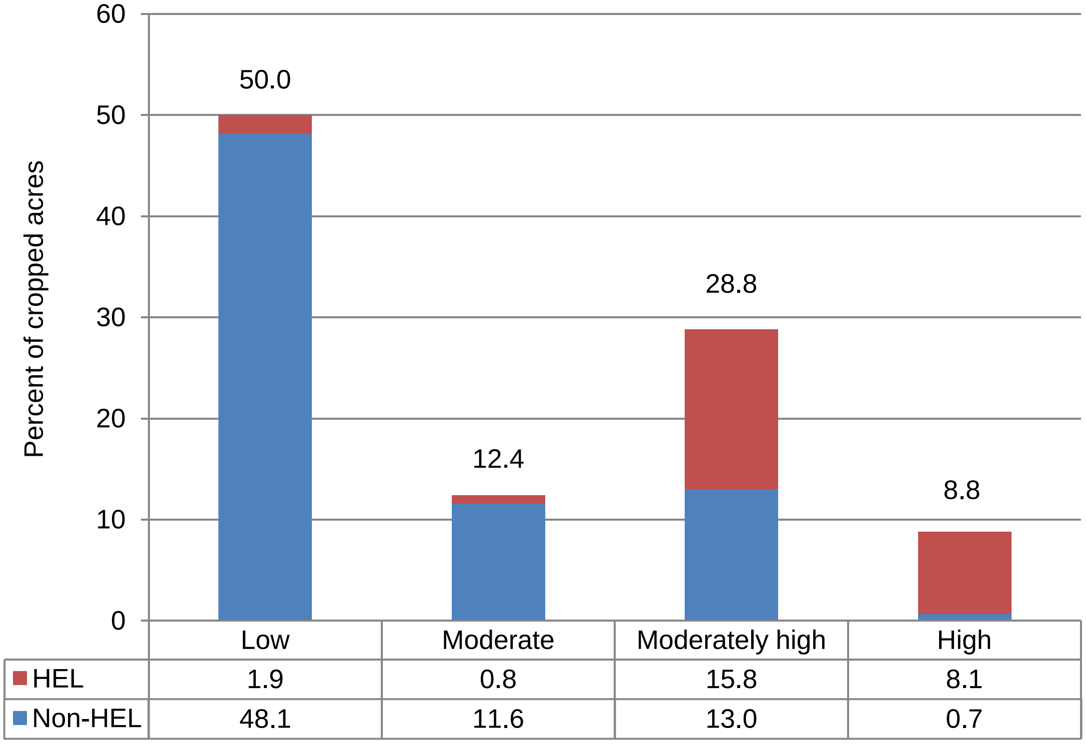
The criteria for the soil runoff potential are presented in figure 52, followed by the spatial distribution of the soil runoff potential within the Ohio-Tennessee River Basin in figure 53. The criteria and spatial distribution for the soil leaching potential are presented in figures 54 and 55.

The maps show the vulnerability potentials for all soils and land uses in the region. For the assessment of conservation treatment needs, however, only the vulnerability potentials for cropped acres were used.

Cropped acres in the Ohio-Tennessee River Basin are a mix of vulnerable and non-vulnerable acres. About 50 percent of cropped acres have a low soil runoff potential (fig. 52). Only 9 percent of the acres have a high soil runoff potential, consisting mostly of highly erodible land, and 29 percent have a moderately high soil runoff potential.

Few cropped acres in this region have a high or moderately high soil leaching potential—8.5 percent (fig. 54). The bulk of cropped acres—79 percent—have a moderate soil leaching potential. The remaining 13 percent have a low soil leaching potential.

Figure 52. Soil runoff potential for cropped acres in the Ohio-Tennessee River Basin



Criteria for four classes of soil runoff potential were derived using a combination of soil hydrologic group, percent slope, and K-factor, as shown in the table below:

Soil runoff potential	Acres with soil hydrologic group A	Acres with soil hydrologic group B	Acres with soil hydrologic group C	Acres with soil hydrologic group D
Low	All acres	Slope<4	Slope<2	Slope<2 and K-factor<0.28
Moderate	None	Slope >=4 and <=6 and K-factor<0.32	Slope >=2 and <=6 and K-factor<0.28	Slope<2 and K-factor>=0.28
Moderately high	None	Slope >=4 and <=6 and K-factor>=0.32	Slope >=2 and <=6 and K-factor>=0.28	Slope >=2 and <=4
High	None	Slope>6	Slope>6	Slope>4

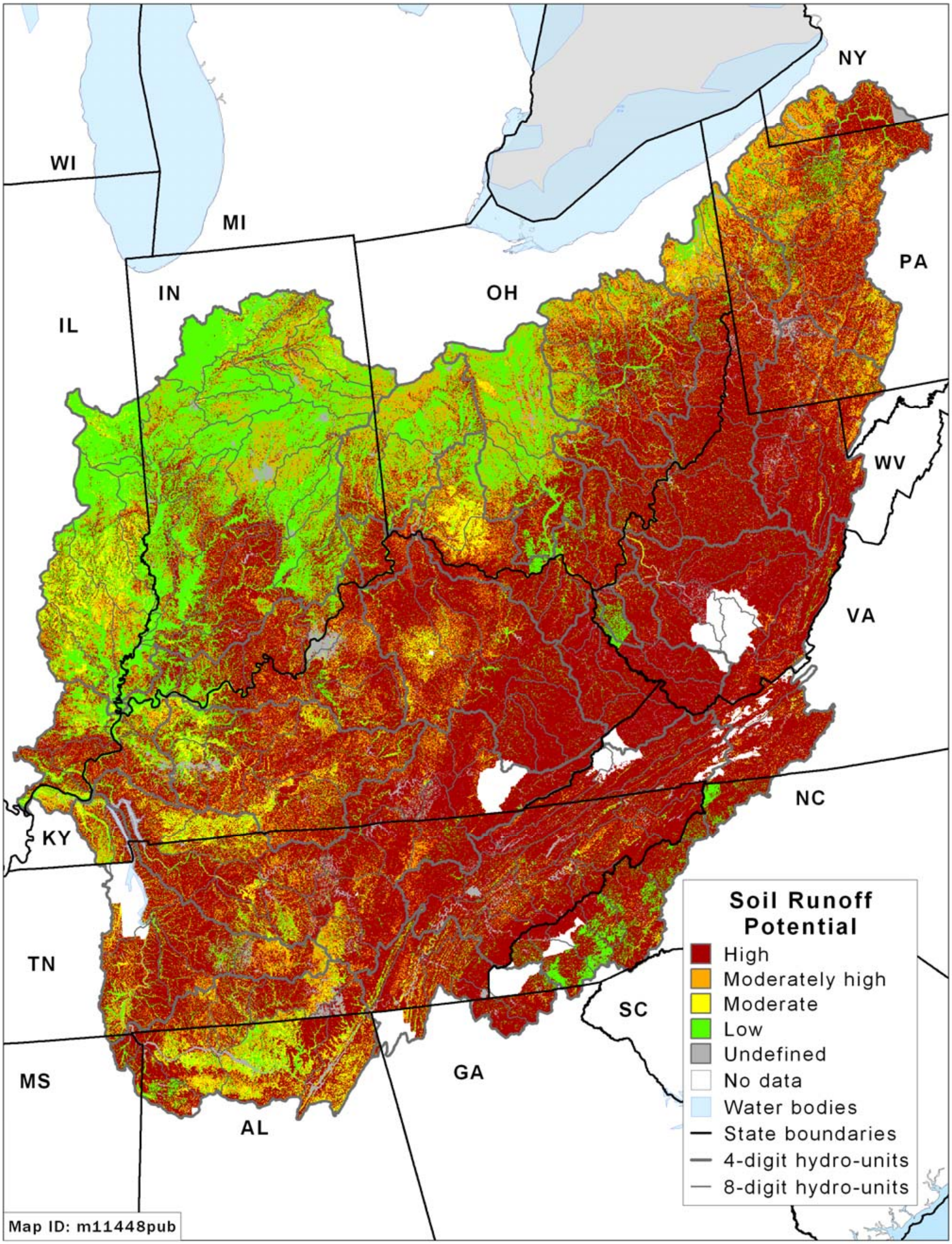
Hydrologic soil groups are classified as:

- **Group A—**sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- **Group D**—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.
Note: About 27 percent of cropped acres in the Ohio-Tennessee River Basin is highly erodible land.

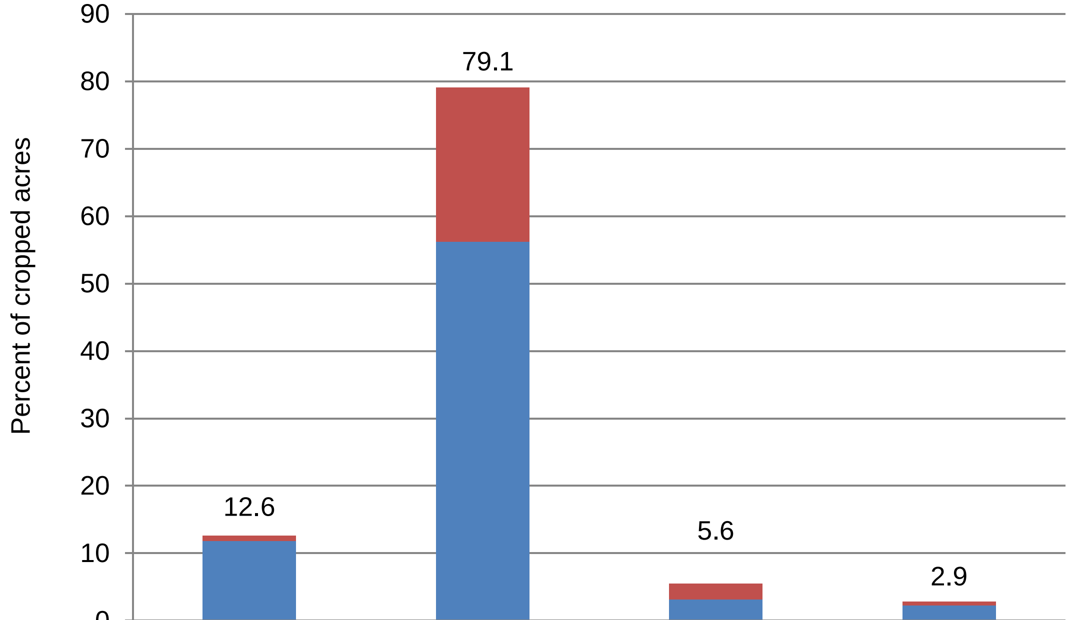
Note: See appendix B, table B4, for a breakdown of soil runoff potential by subregion.

Figure 53. Soil runoff potential for soils in the Ohio-Tennessee River Basin



Note: The soil runoff potential shown in this map was derived using the criteria presented in figure 52 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 54. Soil leaching potential for cropped acres in the Ohio-Tennessee River Basin



	Low	Moderate	Moderately high	High
HEL	0.8	22.9	2.4	0.6
Non-HEL	11.8	56.2	3.2	2.3

Criteria for four classes of soil leaching potential were derived using a combination of soil hydrologic group, percent slope, and K-factor, as shown in the table below:

Soil leaching potential	Acres with soil hydrologic group A	Acres with soil hydrologic group B	Acres with soil hydrologic group C	Acres with soil hydrologic group D
Low	None	None	None	All acres except organic soils
Moderate	None	Slope <=12 and K-factor>=0.24 or slope>12	All acres except organic soils	None
Moderately high	Slope>12	Slope >=3 and <=12 and K-factor<0.24	None	None
High	Slope<=12 or acres classified as organic soils	Slope<3 and K-factor <0.24 or acres classified as organic soils	Acres classified as organic soils	Acres classified as organic soils

Coarse fragments (stones and rocks) in the soil make it easier for water to infiltrate rather than run off. If the coarse fragment content of the soil was greater than 30 percent, the soil leaching potential was increased two levels (moderate and moderately high to high, and low to moderately high). If the coarse fragment content was greater than 10 percent but less than 30 percent, the soil leaching potential was increased one level.

Hydrologic soil groups are classified as:

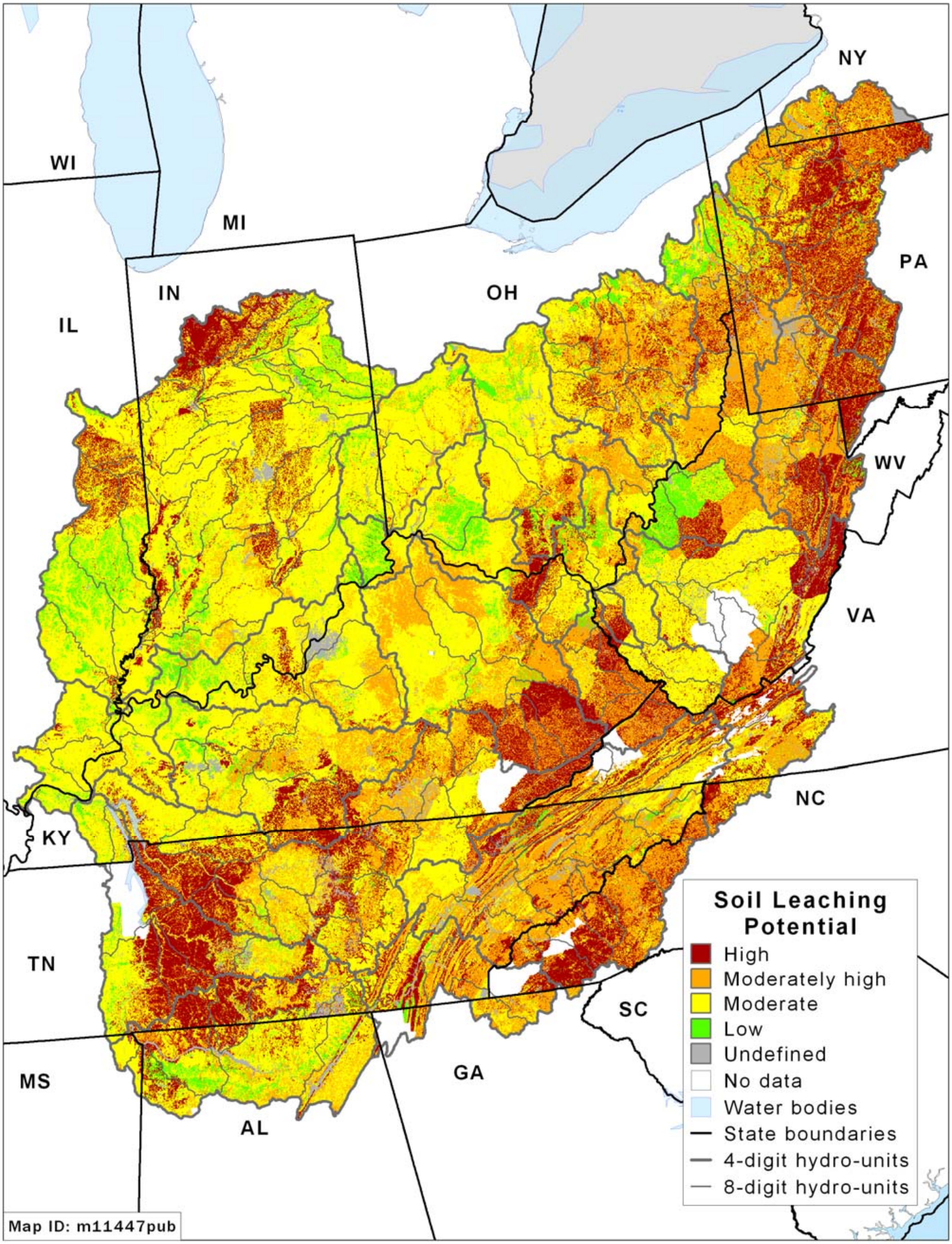
- **Group A—**sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- **Group D**—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

Note: K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.

Note: About 27 percent of cropped acres in the Ohio-Tennessee River Basin is highly erodible land.

Note: See appendix B, table B4, for a breakdown of soil leaching potential by subregion.

Figure 55. Soil leaching potential for soils in the Ohio-Tennessee River Basin

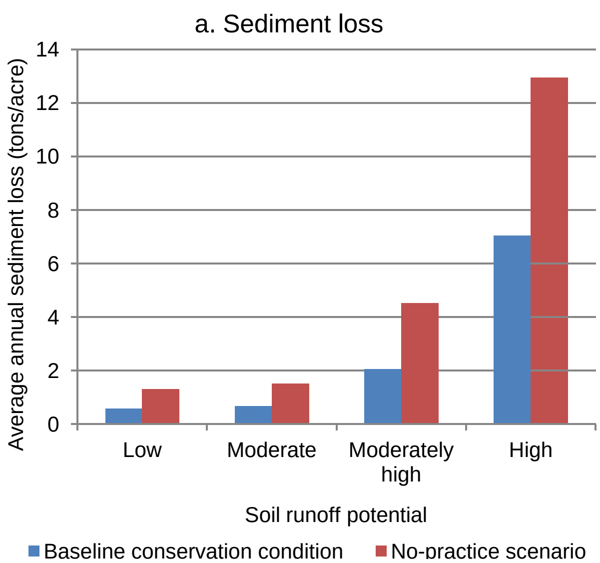


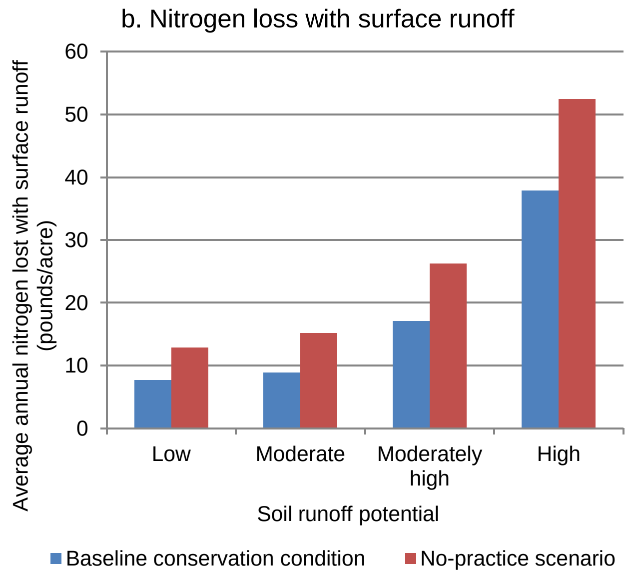
Note: The soil leaching potential shown in this map was derived using the criteria presented in figure 54 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

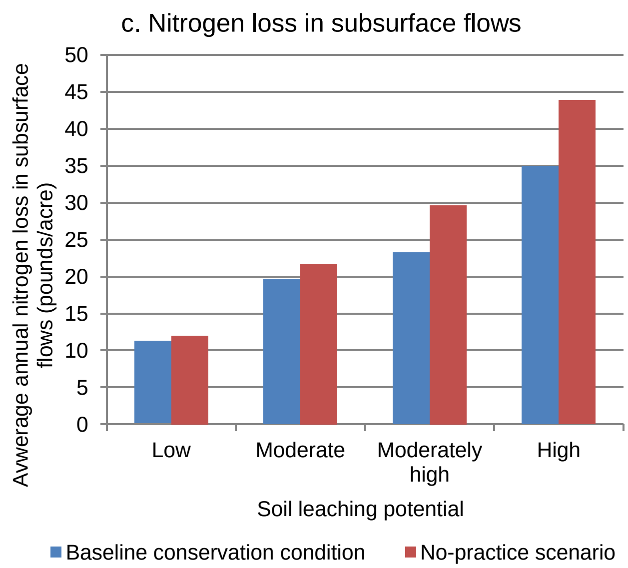
Estimates of sediment and nutrient losses for the no-practice scenario (without conservation practices), presented in figure 56, demonstrate how vulnerability factors influence losses in the Ohio-Tennessee River Basin. Estimates for the baseline are also presented in figure 56 to show how current levels of conservation treatment have reduced losses.)

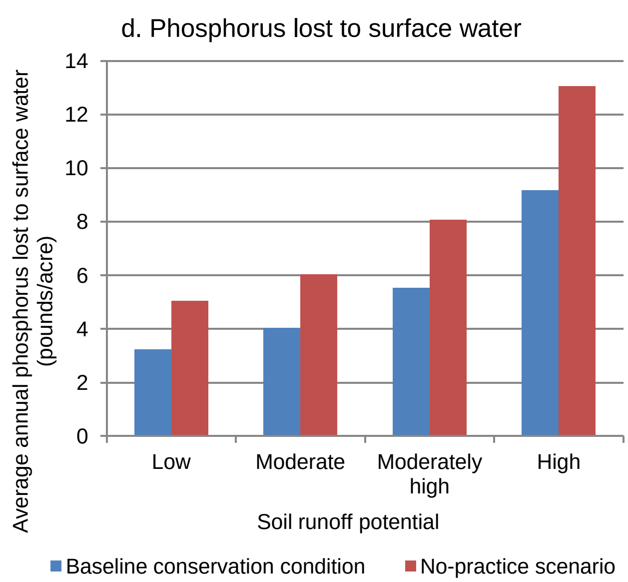
- Sediment loss for the high soil runoff potential would have averaged 13.0 tons per acre per year without conservation practices, compared to 1.3 tons per acre per year for the low soil runoff potential (fig. 56a).
- Nitrogen loss with surface runoff for the high soil runoff potential would have averaged 52 pounds per acre per year, compared to 13 pounds per acre per year for the low soil runoff potential (fig. 56b).
- Nitrogen loss in subsurface flows for the high soil leaching potential would have averaged 44 pounds per acre per year, compared to 12 pounds per acre per year for the low soil leaching potential (fig. 56c).
- Phosphorus lost to surface water for the high soil runoff potential would have averaged 13.1 pounds per acre per year, compared to 5.1 pounds per acre per year for the low soil runoff potential (fig. 56d).

Figure 56. Average annual sediment and nutrient losses for four levels of vulnerability potentials, Ohio-Tennessee River Basin.









Evaluation of Conservation Treatment

The "matrix approach"

A "matrix approach" was used to identify acres where the level of conservation treatment is inadequate relative to the level of inherent vulnerability due to soils and climate. These acres are referred to as "under-treated acres." Cropped acres were divided into 16 groups—four soil vulnerability potentials and four conservation treatment levels. The high or moderately high treatment levels are effective in reducing losses for all soil potentials, as shown in figures 57 through 60 using the results for the baseline conservation condition.

Acres and baseline model results for each of the 16 groupings are presented in the first five matrixes in tables 23 through 26. This matrix approach was very effective in segregating acres with high losses from acres with low losses.

- Estimates of sediment and nutrient loss for the no-practice scenario consistently increased from small losses for the low soil runoff or leaching potential to large losses for the high soil runoff or leaching potential. As the no-practice scenario represents crop production without conservation practices, there is no consistent relationship in loss estimates among the four conservation treatment levels. The differences in losses among conservation treatment levels reflect the underlying variability, which is also influenced by the number of acres in each group.
- Estimates of sediment and nutrient loss for the baseline conservation condition exhibit a nearly consistent trend of decreasing loss with increasing treatment level within each soil runoff or leaching potential.
- The highest losses in the baseline conservation condition were for groups of acres where the conservation treatment level was one step or more below the soil leaching or runoff potential.

The evaluation of conservation treatment needs was conducted by identifying which of the 16 groups of acres are inadequately treated with respect to the soil runoff or soil leaching potential. Three levels of conservation treatment need were identified.

- Acres with a "high" level of need for conservation treatment consist of the most critical under-treated acres in the region. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients.
- Acres with a "moderate" level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability or have more conservation practice use than acres with a high level of need. The treatment level required is not necessarily less, although it can be, but rather the sediment and nutrient losses are lower and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment.

Figure 57. Trend in average annual sediment loss for increasing levels of soil runoff potential at two levels of conservation treatment, Ohio-Tennessee River Basin.

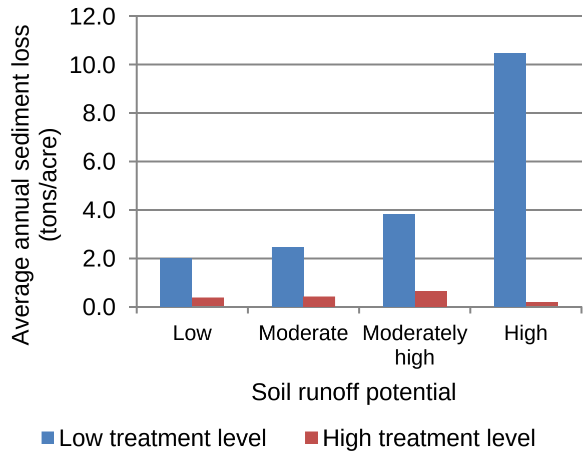
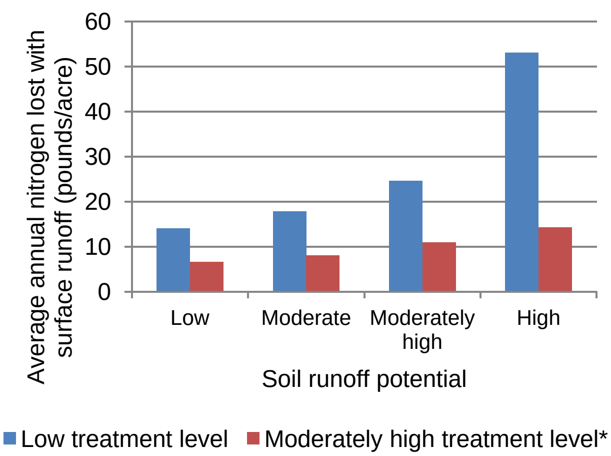
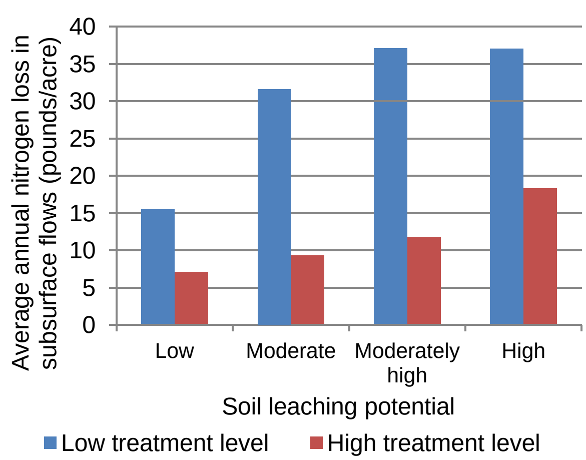


Figure 58. Trend in average annual nitrogen loss with surface runoff for increasing levels of soil runoff potential at two levels of conservation treatment, Ohio-Tennessee River Basin.



* There was not sufficient sample size to report values for the high treatment class.

Figure 59. Trend in average annual nitrogen loss in subsurface flows for increasing levels of soil leaching potential at two levels of conservation treatment, Ohio-Tennessee River Basin



- Acres with a "low" level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. While gains can be obtained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

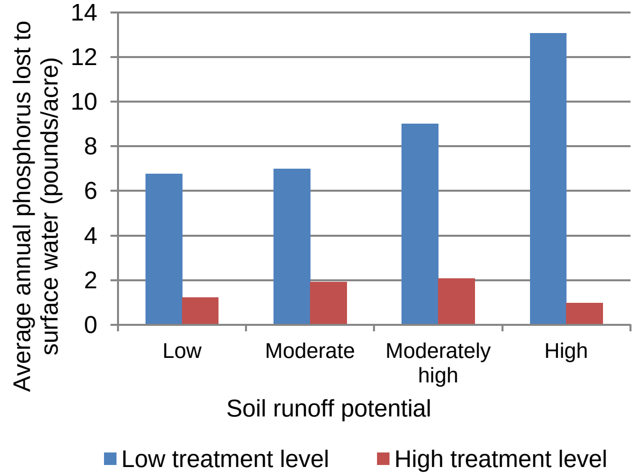
The last two matrixes in each of the tables 23 through 26 shows how conservation treatment needs were identified. Specific criteria were used to identify the groups of acres that fall into each of the three levels of conservation treatment need. Criteria were not tailored to a specific region, but were derived for use in all regions of the country to allow for comparisons of under-treated acres across regions using a consistent analytical framework. The criteria and steps in the process are as follows.

1. The percentage of acres that exceeded a given level of loss was estimated for each cell in the matrix as a guide to determining the extent of excessive losses, shown in tables 23 through 26. These are referred to as "acceptable levels." *Losses above these levels were treated as unacceptable levels of loss.* "Acceptable levels" for field-level losses used in this study are[23]—
   - Average of 2 tons per acre per year for sediment loss
   - Average of 15 pounds per acre per year for nitrogen loss with surface runoff (soluble and sediment attached)
   - Average of 25 pounds per acre per year for nitrogen loss in subsurface flows
   - Average of 4 pounds per acre per year for phosphorus lost to surface water (soluble and sediment attached)
2. Groups of acres with less than 30 percent of the acres exceeding acceptable levels were defined as adequately treated acres and designated as having a **low level of conservation treatment need**.
3. Groups of acres with more than 60 percent of the acres in excess of acceptable levels were designated as having a **high level of conservation treatment need,** indicated by darker shaded cells in the matrixes.
4. The remaining acres were designated as having a **moderate level of conservation treatment need**, indicated by lighter shaded cells in the matrix.

Under-treated acres—those groups of acres with either a high or moderate level of conservation treatment need—are shown in the last matrix in each table. In most cases, under-treated acres consisted of acres where the conservation treatment level was one step or more below the soil leaching or runoff potential (indicated by the red boundary shown in the baseline conservation condition matrix).

[23] The long-term average loss was used as the criteria because losses vary considerably from year to year, and the evaluation is intended to assess the adequacy of conservation treatment over all years, on average. Average annual losses derived from APEX model output simulated over 47 years of actual weather (1960 through 2006) were compared to the acceptable level criteria for each sample point.

Figure 60. Trend in average annual phosphorus lost to surface water for increasing levels of soil runoff potential at two levels of conservation treatment, Ohio-Tennessee River Basin.



Why Was a Threshold Approach Not Used?

A threshold approach is where all acres with edge-of-field losses above a specific level are identified as under-treated acres; and thus, all acres below that level of loss are considered adequately treated. A threshold approach is often used in regulatory schemes to denote compliance versus non-compliance.

A threshold approach is impractical for use in evaluating the adequacy of conservation practice use at the field level. Determination of the threshold level would need to be based on the environmental goals for a watershed, which would be expected to vary from watershed to watershed. In fact, different thresholds would likely be needed for each field, depending on the cropping system. Moreover, sediment and nutrient losses vary from year to year; a specific set of practices shown to reduce losses below a specific level in some years will fail to do so in other years, even among acres that are fully treated. Inexpensive monitoring technologies do not exist for estimating sediment and nutrient losses on a field-by-field basis to determine what level of treatment is needed to meet an edge-of-field loss threshold, further hampering adaptive management efforts by producers.

The conservation goal is full treatment—not treatment to an arbitrary threshold. Protocols for full treatment—avoid, control, and trap—apply equally to all fields in all settings. The hallmark of the matrix approach is that the acres with treatment needs can be readily identified by farmers and conservation planners and treated as needed. Soil vulnerability levels and the existing conservation treatment levels can be readily determined during the conservation planning process.

Acceptable levels were initially derived through a series of forums held at professional meetings of researchers working on fate and transport of sediment and nutrients in agriculture. Those meetings produced a range of estimates for edge-of-field sediment loss, nitrogen loss, and phosphorus loss, representing what could be realistically achieved with today's production and conservation technologies. The range was narrowed by further examination of APEX model output, which also showed that the levels selected were agronomically feasible in all agricultural regions of the country. In the Ohio-Tennessee River Basin, for example, percentages of acres that can attain these acceptable levels with additional soil erosion control and nutrient management practices on all under-treated acres are (see the next chapter)—

- 99 percent of cropped acres for sediment loss,
- 98 percent of cropped acres for nitrogen loss with surface runoff,
- 95 percent of cropped acres for nitrogen loss in subsurface flows,
- 95 percent of cropped acres for phosphorus lost to surface water, and

The criteria used to identify acres that need additional conservation treatment, including acceptable levels, are not intended to provide adequate protection of water quality, although for some environmental settings they may be suitable for that purpose. Evaluation of how much conservation treatment is needed to meet Federal, State, and/or local water quality goals in the region is beyond the scope of this study.

Table 23. Identification of under-treated acres for sediment loss due to water erosion in the Ohio-Tennessee River Basin

Soil runoff potential	Conservation treatment levels for water erosion control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	326,956	3,089,129	829,945	8,267,898	12,513,929
Moderate	106,711	725,314	131,727	2,147,812	3,111,564
Moderately high	1,486,194	2,934,571	1,050,945	1,741,480	7,213,189
High	789,788	1,106,158	252,855	51,417	2,200,218
All	2,709,648	7,855,173	2,265,472	12,208,607	25,038,900
Percent of cropped acres					
Low	1	12	3	33	50
Moderate	0	3	1	9	12
Moderately high	6	12	4	7	29
High	3	4	1	<1	9
All	11	31	9	49	100
Sediment loss estimates *without* conservation practices (no-practice scenario, average annual tons/acre)					
Low	2.37	1.75	1.67	1.07	1.31
Moderate	3.26	2.16	2.09	1.19	1.53
Moderately high	5.32	5.04	5.28	2.54	4.53
High	14.07	12.72	11.21	9.75	12.96
All	7.43	4.56	4.43	1.33	3.29
Sediment loss estimates for the baseline conservation condition (average annual tons/acre)					
Low	2.02	0.96	0.53	0.39	0.58
Moderate	2.47	1.26	0.34	0.42	0.68
Moderately high	3.82	2.32	1.18	0.65	2.06
High	10.48	6.25	1.17	0.21	7.04
All	5.49	2.24	0.89	0.43	1.59
Percent reduction in sediment loss due to conservation practices					
Low	15	45	68	63	55
Moderate	24	42	84	65	55
Moderately high	28	54	78	74	54
High	26	51	90	98	46
All	26	51	80	68	52
Percent of acres in baseline conservation condition with average annual sediment loss more than 2 tons/acre					
Low	23	11	0	1	4
Moderate	27	17	0	0	5
Moderately high	64	36	19	3	31
High	97	81	23	0	78
All	67	31	11	1	18
Estimate of under-treated acres					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	1,486,194	2,934,571	0	0	4,420,765
High	789,788	1,106,158	0	0	1,895,945
All	2,275,981	4,040,729	0	0	6,316,710

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil runoff potential. These cells consistently had the highest losses in the model simulations.

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

Table 24. Identification of under-treated acres for nitrogen loss with surface runoff (sediment attached and soluble) in the Ohio-Tennessee River Basin

Soil runoff potential	Conservation treatment levels for nitrogen runoff control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	329,664	4,486,500	6,735,345	962,420	12,513,929
Moderate	71,632	945,417	1,844,591	249,924	3,111,564
Moderately high	1,109,766	3,885,832	1,927,431	290,159	7,213,189
High	514,665	1,481,015	204,538	0	2,200,218
All	2,025,727	10,798,764	10,711,905	1,502,504	25,038,900
Percent of cropped acres					
Low	1	18	27	4	50
Moderate	<1	4	7	1	12
Moderately high	4	16	8	1	29
High	2	6	1	0	9
All	8	43	43	6	100
Estimates of nitrogen loss with surface runoff *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	19.1	15.1	11.6	8.6	12.8
Moderate	22.6	17.0	14.5	11.4	15.2
Moderately high	31.6	27.9	21.5	14.8	26.2
High	61.2	50.6	44.2	NA	52.5
All	36.8	24.8	14.5	10.2	20.5
Estimates of nitrogen loss with surface runoff for the baseline conservation condition (average annual pounds/acre)					
Low	14.1	9.7	6.7	4.0	7.7
Moderate	17.9	10.9	8.1	5.1	8.9
Moderately high	24.7	18.7	10.9	7.4	17.1
High	53.0	35.9	14.3	NA	37.9
All	29.9	16.6	7.8	4.8	13.2
Percent reduction in nitrogen loss with surface runoff due to conservation practices					
Low	26	36	43	54	40
Moderate	21	36	45	55	41
Moderately high	22	33	49	50	35
High	13	29	68	NA	28
All	19	33	46	53	35
Percent of acres in baseline conservation condition with average annual nitrogen loss with surface runoff more than 15 pounds/acre					
Low	29	16	4	0	9
Moderate	23	13	4	0	7
Moderately high	75	52	18	0	45
High	100	84	32	NA	83
All	72	38	7	0	25
Estimate of under-treated acres for nitrogen loss with surface runoff					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	1,109,766	3,885,832	0	0	4,995,599
High	514,665	1,481,015	204,538	0	2,200,218
All	1,624,431	5,366,848	204,538	0	7,195,816

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil runoff potential. These cells consistently had the highest losses in the model simulations.
Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.
Note: NA indicates not applicable because there were no acres in the category.

Table 25. Identification of under-treated acres for nitrogen loss in subsurface flows in the Ohio-Tennessee River Basin

Soil leaching potential	Conservation treatment levels for nitrogen management: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	456,186	1,117,221	1,068,065	507,955	3,149,428
Moderate	3,090,190	8,518,074	5,468,533	2,714,220	19,791,016
Moderately high	193,447	615,359	342,726	232,745	1,384,277
High	87,813	363,533	142,338	120,495	714,179
All	3,827,636	10,614,187	7,021,662	3,575,415	25,038,900
Percent of cropped acres					
Low	2	4	4	2	13
Moderate	12	34	22	11	79
Moderately high	1	2	1	1	6
High	0	1	1	<1	3
All	15	42	28	14	100
Estimates of nitrogen loss in subsurface flows *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	13.4	13.3	11.1	9.7	12.0
Moderate	32.8	23.4	17.0	13.5	21.7
Moderately high	45.8	30.4	25.1	20.8	29.6
High	50.6	48.6	37.9	32.0	43.9
All	31.6	23.6	16.9	14.0	21.6
Estimates of nitrogen loss in subsurface flows for the baseline conservation condition (average annual pounds/acre)					
Low	15.5	14.5	8.2	7.1	11.3
Moderate	31.6	24.1	11.1	9.3	19.7
Moderately high	37.1	27.9	14.8	11.8	23.3
High	37.0	44.3	24.0	18.3	35.0
All	30.1	24.0	11.1	9.5	19.2
Percent reduction in nitrogen loss in subsurface flows due to conservation practices					
Low	-16	-9	27	27	6
Moderate	4	-3	35	31	10
Moderately high	19	8	41	43	22
High	27	9	37	43	20
All	5	-2	34	33	11
Percent of acres in baseline conservation condition with average annual nitrogen loss in subsurface flows more than 25 pounds/acre					
Low	9	15	0	0	7
Moderate	46	29	2	0	20
Moderately high	46	44	8	0	28
High	71	76	23	10	54
All	42	30	3	1	20
Estimate of under-treated acres for nitrogen loss in subsurface flows					
Low	0	0	0	0	0
Moderate	3,090,190	0	0	0	3,090,190
Moderately high	193,447	615,359	0	0	808,806
High	87,813	363,533	0	0	451,346
All	3,371,450	978,892	0	0	4,350,342

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil leaching potential. These cells consistently had the highest losses in the model simulations.

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

Table 26. Identification of under-treated acres for phosphorus lost to surface water (phosphorus attached to sediment and in solution, including soluble phosphorus in subsurface lateral flow pathways) in the Ohio-Tennessee River Basin

Soil runoff potential	Conservation treatment levels for phosphorus runoff control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	974,984	5,710,507	4,074,308	1,754,131	12,513,929
Moderate	258,114	1,355,310	986,572	511,568	3,111,564
Moderately high	1,700,719	3,653,340	1,565,262	293,868	7,213,189
High	967,999	1,046,032	173,109	13,078	2,200,218
All	3,901,815	11,765,189	6,799,251	2,572,645	25,038,900
Percent of cropped acres					
Low	4	23	16	7	50
Moderate	1	5	4	2	12
Moderately high	7	15	6	1	29
High	4	4	1	<1	9
All	16	47	27	10	100
Phosphorus lost to surface water *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	7.71	5.01	4.69	4.54	5.05
Moderate	7.09	5.82	5.89	6.42	6.05
Moderately high	9.86	7.84	6.83	7.28	8.08
High	14.85	11.92	10.47	6.34	13.06
All	10.38	6.60	5.50	5.23	6.75
Phosphorus lost to surface water for the baseline conservation condition (average annual pounds/acre)					
Low	6.77	4.25	1.82	1.21	3.23
Moderate	6.99	5.40	2.53	1.91	4.05
Moderately high	9.01	5.38	2.76	2.09	5.54
High	13.08	6.67	3.18	0.98	9.18
All	9.33	4.95	2.18	1.45	4.52
Percent reduction in phosphorus lost to surface water due to conservation practices					
Low	12	15	61	73	36
Moderate	1	7	57	70	33
Moderately high	9	31	60	71	31
High	12	44	70	85	30
All	10	25	60	72	33
Percent of acres in baseline conservation condition with average annual phosphorus lost to surface water more than 4 pounds/acre					
Low	68	34	5	1	23
Moderate	65	50	11	0	31
Moderately high	82	49	17	2	48
High	97	65	31	0	76
All	81	43	9	1	36
Estimate of under-treated acres for phosphorus lost to surface water					
Low	974,984	5,710,507	0	0	6,685,490
Moderate	258,114	1,355,310	0	0	1,613,424
Moderately high	1,700,719	3,653,340	0	0	5,354,059
High	967,999	1,046,032	173,109	0	2,187,140
All	3,901,815	11,765,189	173,109	0	15,840,113

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil runoff potential. These cells consistently had the highest losses in the model simulations.

Note: Color-shaded cells indicate under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

Conservation treatment needs by resource concern

The proportion of cropped acres with a high or moderate need for additional conservation treatment was determined to be (fig. 61)—

- 25 percent for sediment loss (13.5 percent with a high need for treatment),
- 29 percent for nitrogen loss with runoff (12 percent with a high need for treatment),
- 63 percent for phosphorus lost to surface water (20 percent with a high need for treatment),
- 17 percent for nitrogen loss in subsurface flows (2 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Under-treated acres in the Ohio-Tennessee River Basin are presented by combinations of resource concerns in table 27. About half of the under-treated acres are under-treated for only one of the four resource concerns, usually phosphorus runoff:

- 42 percent of under-treated acres are under-treated only for phosphorus runoff,
- 6 percent of under-treated acres are under-treated only for nitrogen leaching, and
- about 1 percent of under-treated acres are under-treated for sediment loss only and another 1 percent for nitrogen runoff only.

One-fourth of under-treated acres need additional treatment for the three resource concerns related to runoff. Another 10 percent need treatment for nitrogen leaching and phosphorus runoff. Only about 7 percent of under-treated acres were determined to be under-treated for all four resource concerns.

The most critical conservation concern in the region is the need for complete and consistent use of nutrient management—appropriate rate, form, timing, *and* method of application, especially for phosphorus loss (table 27). Additional erosion control is also needed.

Figure 61. Percent of cropped acres that are under-treated in the Ohio-Tennessee River Basin, by resource concern

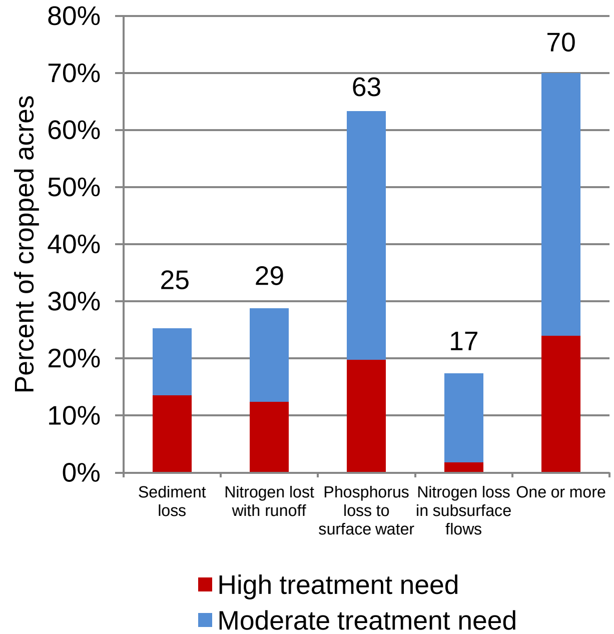


Table 27. Under-treated acres with resource concerns needing treatment in the Ohio-Tennessee River Basin

Reason for treatment need	Estimated acres needing treatment	Percent of cropped acres	Percent of under-treated acres
Phosphorus runoff only	7,371,726	29.4	42.1
Sediment loss, nitrogen runoff and phosphorus runoff	4,444,244	17.7	25.4
Nitrogen leaching and phosphorus runoff	1,750,019	7.0	10.0
Sediment loss, nitrogen and phosphorus runoff, and nitrogen leaching	1,212,333	4.8	6.9
Nitrogen leaching only	962,546	3.8	5.5
Phosphorus runoff and nitrogen runoff	584,201	2.3	3.3
Sediment loss and nitrogen runoff	379,239	1.5	2.2
Nitrogen runoff, nitrogen leaching and phosphorus runoff	353,694	1.4	2.0
Sediment loss only	134,899	0.5	0.8
Nitrogen runoff only	129,397	0.5	0.7
Sediment loss and phosphorus runoff	102,939	0.4	0.6
Nitrogen leaching and nitrogen runoff	49,653	0.2	0.3
Sediment loss, nitrogen runoff, and nitrogen leaching	22,098	0.1	0.1
Sediment loss, nitrogen runoff. and phosphorus runoff	20,956	0.1	0.1
All under-treated acres	17,517,945	70.0	100.0

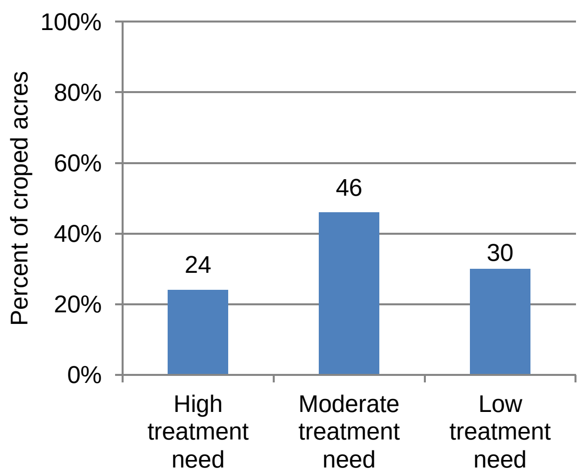
Note: This table summarizes the under-treated acres identified in tables 23-26 and reports the joint set of acres that need treatment according to combinations of resource concerns.
Note: Percents may not add to totals because of rounding.

Conservation treatment needs for one or more resource concern

Some acres require additional treatment for only one of the five resource concerns, while other acres require additional treatment for two or more resource concerns. After accounting for acres that need treatment for multiple resource concerns, the evaluation of treatment needs for the Ohio-Tennessee River Basin determined the following (fig. 62):

- 24 percent of cropped acres (6.0 million acres) have a **high** level of need for additional conservation treatment,
- 46 percent of cropped acres (11.5 million acres) have a **moderate** level of need for additional conservation treatment, and
- 30 percent of cropped acres (7.5 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

Figure 62. Percent of cropped acres with a high, moderate, or low level of need for additional conservation treatment for one or more resource concern in the Ohio-Tennessee River Basin



High level of need for conservation treatment. Acres with a "high" level of need for conservation treatment consist of the most critical under-treated acres in the region (table 28 and figs. 63 through 66). These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients. These acres lose (per acre per year, on average)—

- 4.27 tons of sediment by water erosion,
- 7.7 pounds of phosphorus,
- 25 pounds of nitrogen with surface runoff, and
- 24 pounds of nitrogen in subsurface flows.

Acres with a high level of treatment need have the greatest potential for reducing agricultural pollutant loadings with additional conservation treatment.

Moderate level of need for conservation treatment. Acres with a "moderate" level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability and/or have more conservation practice use than acres with a high level of need (table 28 and figs. 63 through 66).The sediment and nutrient losses are lower than those with a high need for additional treatment and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment. These acres lose (per acre per year, on average)—

- 0.89 ton of sediment by water erosion,
- 4.5 pounds of phosphorus,
- 11 pounds of nitrogen with surface runoff, and
- 20 pounds of nitrogen in subsurface flows.

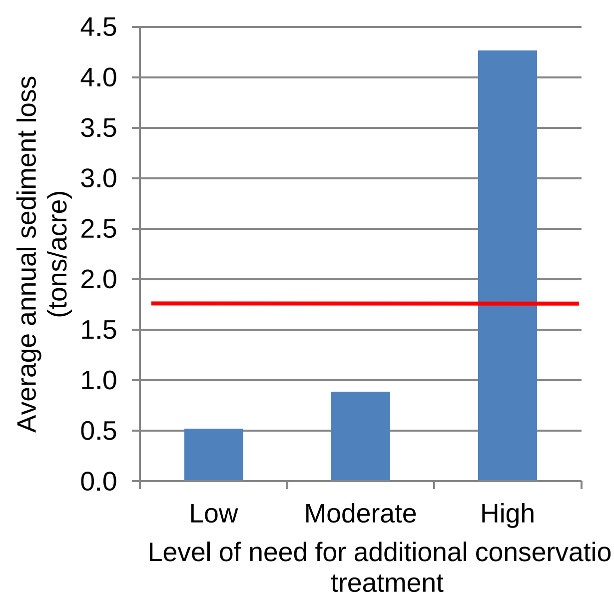
While the benefit of additional treatment of acres with a moderate level of treatment need is less than for acres with a high level of treatment need, a portion of these acres may need to be treated to meet water quality goals in the region.

Low level of need for conservation treatment. Acres with a low level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability (table 28 and figs. 63 through 66). These acres lose (per acre per year, on average)—

- 0.52 ton of sediment by water erosion,
- 1.9 pounds of phosphorus,
- 7 pounds of nitrogen with surface runoff, and
- 14 pounds of nitrogen in subsurface flows.

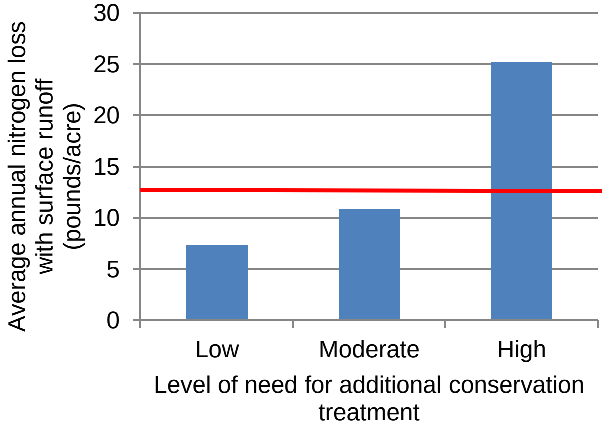
While gains can be obtained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

Figure 63. Average per-acre sediment loss for three levels of conservation treatment need for one or more resource concerns, Ohio-Tennessee River Basin



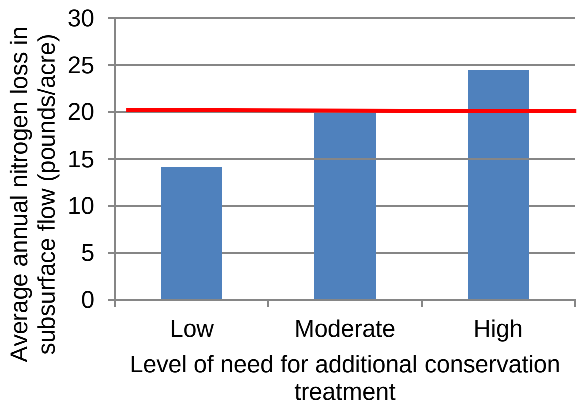
Note: The average sediment loss for all cropped acres is 1.59 tons per acre per year, shown in red.

Figure 64. Average per-acre nitrogen lost with surface runoff for three levels of conservation treatment need for one or more resource concerns, Ohio-Tennessee River Basin



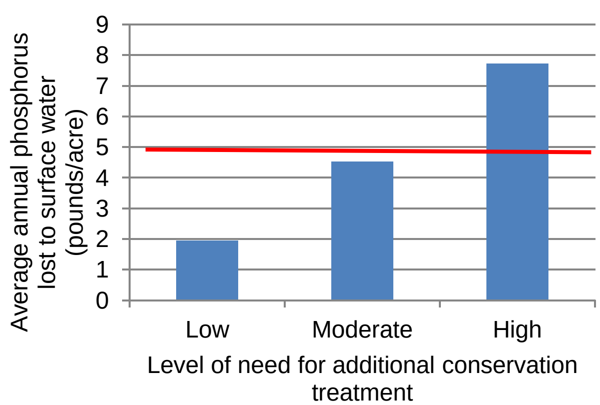
Note: The average nitrogen loss with surface water for all cropped acres is 13.2 pounds per acre per year, shown in red.

Figure 65. Average per-acre nitrogen loss in subsurface flow pathways for three levels of conservation treatment need for one or more resource concerns, Ohio-Tennessee River Basin



Note: The average nitrogen loss in subsurface flow pathways for all cropped acres is 19.2 pounds per acre per year, shown in red.

Figure 66. Average per-acre phosphorus lost to surface water for three levels of conservation treatment need for one or more resource concerns, Ohio-Tennessee River Basin



Note: The average phosphorus lost to surface water for all cropped acres is 4.52 pounds per acre per year, shown in red.

What is "Adequate Conservation Treatment?"

A field with adequate conservation practice use will have combinations of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses. Full treatment consists of a suite of practices that—

- avoid or limit the potential for contaminant losses by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- control overland flow where needed; and
- trap materials leaving the field using appropriate edge-of-field mitigation.

Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment, nutrient, and pesticide losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to soluble nutrient and pesticide losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

In practice, a *comprehensive planning process* is used to identify the appropriate combination of nutrient management techniques, soil erosion control practices, and other conservation practices needed to address the specific inherent vulnerabilities associated with each field.

In this report, adequate conservation treatment is limited to the use of practices that will not require changes in the cropping systems or changes in regional crop production levels. It may be necessary in some environmental settings to go beyond "adequate conservation treatment" to achieve local environmental goals.

Table 28. Baseline conservation condition model simulation results for subsets of under-treated and adequately treated acres in the Ohio-Tennessee River Basin

Model simulated outcome	Acres with a *low* need for treatment	Acres with a *moderate* need for treatment	Acres with a *high* need for treatment	All acres
Cultivated cropland acres in subset	7,520,955	11,505,660	6,012,285	25,038,900
Percent of acres	30.0%	46.0%	24.0%	100.0%
Water flow				
Average annual surface runoff (inches)	7.23	7.53	8.30	7.62
Average annual subsurface water flow (inches)	9.13	9.15	9.80	9.30
Erosion and sediment loss				
Average annual wind erosion (tons/acre)	0.02	0.02	0.04	0.02
Average annual sheet and rill erosion (tons/acre)	0.49	0.82	2.57	1.14
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.52	0.89	4.27	1.59
Soil organic carbon				
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	78	62	-103	27
Nitrogen				
Nitrogen sources (pounds/acre)				
Atmospheric deposition	8	8	9	8
Bio-fixation by legumes	71	66	52	64
Nitrogen applied as commercial fertilizer and manure	72	87	92	84
All nitrogen sources	151	162	153	156
Nitrogen in crop yield removed at harvest (pounds/acre)	117	118	104	114
Total nitrogen loss for all pathways (pounds/acre)	31	42	60	43
Average annual loss of nitrogen through volatilization (pounds/acre)	7.1	8.2	6.8	7.5
Average annual nitrogen returned to the atmosphere through denitrification (pounds/acre)	1.9	2.6	3.0	2.5
Average annual loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	7.3	10.8	25.1	13.2
Average annual nitrogen loss in subsurface flows (pounds/acre)	14.1	19.9	24.5	19.2
Phosphorus				
Phosphorus applied (pounds/acre)	19.3	26.1	27.6	24.4
Total phosphorus loss for all pathways (pounds/acre)	2.0	4.6	7.8	4.6
Loss of phosphorus to surface water, including both soluble and sediment attached (pounds/acre)*	1.9	4.5	7.7	4.5
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	21.8	27.3	35.2	27.5
Average annual surface water pesticide risk indicator for aquatic ecosystem	3.6	5.1	4.0	4.4
Average annual surface water pesticide risk indicator for humans	0.8	1.0	0.9	0.9

* Includes phosphorus lost with waterborne sediment and soluble phosphorus in subsurface flows that are intercepted by tile drains and drainage ditches, lateral subsurface outflow (seeps), and groundwater return flow.

Conservation treatment needs by cropping systems

The breakdown of under-treated acres by cropping system showed a generally proportionate distribution of under-treated acres among cropping systems, shown in table 29. Percentages of under-treated acres are close to the same percentages of the region's cultivated cropland in each subregion. However, for the critical under-treated acres (acres with a high need for treatment), corn-soybean rotations have a disproportionately lower percentage of acres that need additional treatment. Corn-soybean rotations make up 69 percent of the cropped acres in the region, but only 49 percent of critical under-treated acres in the region (table 29). Overall, only 17 percent of corn-soybean rotations are critically under-treated. Most of the other cropping systems in this region have a disproportionately higher number of acres needing additional conservation treatment. The most striking are corn only, corn and close-grown crops, hay-crop mixes, and remaining crop mixes. For these cropping systems, 47 to 70 percent of the acres are critically under-treated (table 29).

Conservation treatment needs by subregions

Under-treated acres in the Ohio-Tennessee River Basin are presented in table 30 by subregion. Percentages of under-treated acres are fairly close to the percentages of the region's cultivated cropland in each subregion, indicating that under-treated acres are spread proportionately throughout the region (table 30). Critical under-treated acres, however, are disproportionately high in seven subregions. The most striking are the Allegheny and Monongahela River subregions and the Muskingum River subregion, where 70 and 50 percent of the acres are critically under-treated, respectively.

In contrast, the Wabash-Patoka-White River subregion has a sharply disproportionately lower number of under-treated acres. This subregion has 52 percent of the cropped acres in the region, but only 35 percent of the critical acres and 47 of undertreated acres (table 30). Only 16 percent of the cropped acres in this subregion are critically under-treated.

(See appendix B, table B5, for a breakdown of conservation treatment needs by subregion.)

Table 29. Under-treated acres by cropping system in the Ohio-Tennessee River Basin

		Critical under-treated acres (acres with a *high* level of treatment need)			All under-treated acres (acres with a *high* or *moderate* level of treatment need)		
Subregion name	Percent of cropped acres in Ohio-Tennessee River Basin	Acres	Percent of acres in Ohio-Tennessee River Basin	Percent of acres in cropping system	Acres	Percent of acres in Ohio-Tennessee River Basin	Percent of acres in cropping system
Corn-soybean only	69	2,966,955	49	17	11,130,683	64	65
Corn-soybean with close grown crops	9	632,151	11	27	1,943,616	11	82
Corn only	5	621,839	10	47	1,041,359	6	78
Corn and close grown crops	2	287,737	5	70	329,545	2	80
Soybean-wheat only	2	176,608	3	37	415,253	2	87
Soybean only	5	312,087	5	24	896,136	5	69
Hay-crop mix	4	506,564	8	49	900,702	5	87
Remaining mix of crops	4	508,343	8	54	860,650	5	92
Total	100	6,012,285	100	24	17,517,945	100	70

Note: Percents may not add to totals because of rounding.

Table 30. Under-treated acres for subregions in the Ohio-Tennessee River Basin*

			Critical under-treated acres (acres with a *high* level of treatment need)			All under-treated acres (acres with a *high* or *moderate* level of treatment need)		
Sub-region code	Subregion name	Percent of cropped acres in Ohio-Tennessee River Basin	Acres	Percent of acres in Ohio-Tennessee River Basin	Percent of acres in subregion	Acres	Percent of acres in Ohio-Tennessee River Basin	Percent of acres in subregion
0501, 0502	Allegheny and Monongahela River subregions	2	355,307	6	70	479,318	3	95
0503	Upper Ohio-Beaver-Little Kanawha River subregion	2	224,912	4	42	424,746	2	79
0504	Muskingum River subregion	4	512,284	9	50	780,919	4	77
0505, 0506, 0507	Scioto, Kanawha, and Guyandotte-Big Sandy River subregions**	8	354,965	6	18	1,401,362	8	70
0508	Great Miami subregion	7	395,717	7	21	1,262,958	7	68
0509	Middle Ohio-Raccoon-Little-Miami River subregion	4	214,538	4	22	667,982	4	68
0510, 0511	Licking-Kentucky and Green River subregions	5	389,868	6	30	1,089,645	6	84
0512	Wabash-Patoka-White River subregion	52	2,076,579	35	16	8,245,343	47	64
0513	Upper and Lower Cumberland River subregion	3	226,962	4	28	719,658	4	88
0514	Lower Ohio-Salt River subregion	7	735,134	12	41	1,373,096	8	77
0601, 0602, 0603	Upper and Middle Tennessee River subregions	4	385,603	6	41	724,112	4	77
0604	Lower Tennessee including Duck River subregion	2	140,415	2	37	348,808	2	92
	Total	100	6,012,285	100	24	17,517,945	100	70

* Some subregions have been combined for reporting because of small sample size.
** The bulk of the cropped acres in this grouping are in the Scioto River Basin.
Note: Percents may not add to totals because of rounding.

Chapter 6
Assessment of Potential Field-Level Gains from Further Conservation Treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Ohio-Tennessee River Basin. The simulated treatment levels were designed to minimally affect crop yields and maintain regional production capacity for food, fiber, forage, and fuel. The existing practices were augmented with additional practices to—

- avoid or limit the potential for loss by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- control overland flow where needed; and
- trap materials leaving the field using appropriate edge-of-field mitigation where absent.

Two sets of conservation practices were simulated:

1. Additional water erosion control practices consisting of three types of structural practices—overland flow practices, concentrated flow practices, and edge-of-field mitigation), and
2. Application of nitrogen and phosphorus using appropriate rate, timing, and method.

Four conservation treatment scenarios were simulated to evaluate the potential gains from further conservation treatment:

1. Treatment of the 6.0 million critical under-treated acres (acres with a high need for conservation treatment) with water erosion control practices only.
2. Treatment of all 17.5 million under-treated acres (acres with a high or moderate need for conservation treatment) with water erosion control practices only.
3. Treatment of the 6.0 million critical under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.
4. Treatment of all 17.5 million under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.

The specific conservation practices used in the simulated treatments are not intended to be a prescription for how to construct conservation plans, but rather are a general representation of sets or suites of conservation practices that could be used to address multiple resource concerns. In actual planning situations a variety of alternative practice scenarios would be presented to the producer and selections would be based on the level of treatment need, cost of conservation implementation, impact on production goals, and preferences of the farm operator.

In the derivation of conservation plans, other conservation practices would be considered, such as cover crops, tillage and residue management, conservation crop rotations, drainage water management, and emerging conservation technologies. Only erosion control structural practices and consistent nutrient management techniques were simulated here to serve as a proxy for the more comprehensive suite of practices that is obtained through the conservation planning process. For example, a conservation plan may include tillage and residue management and cover crops instead of some of the structural practices included in the model simulation. Similarly, drainage water management or cover crops might be used as a substitute for—or in addition to—strict adherence to the right rate, timing, and method of nutrient application.

Long-term conserving cover was not included in the treatment scenarios. Long-term conserving cover represents the ultimate conservation treatment for acres that are highly vulnerable to sediment and nutrient loss, but if it was widely used, regional crop production levels could not be maintained. Enrolling more cultivated cropland acres in programs that provide the economic incentives for long-term conserving cover may be necessary in some areas to meet water quality goals for environmental protection.

Pesticide management was also not addressed directly in the treatment scenarios. While erosion control practices influence pesticide transport and loss, significant reductions in pesticide edge-of-field environmental risk within the region will require more intensive Integrated Pest Management (IPM) practices, including pesticide substitutions. Simulation of additional IPM and any associated pesticide substitutions is site specific and requires more information about the sample fields than was available from the farmer survey.

The level of conservation treatment is simulated to show *potential* environmental benefits, but is not designed to achieve specific environmental protection goals.

Treatment scenarios were also not designed to represent actual program or policy options for the Ohio-Tennessee River Basin.

Economic and programmatic aspects—such as producer costs, conservation program costs, and capacity to deliver the required technical assistance—were not considered in the assessment of the potential gains from further conservation treatment.

Simulation of Additional Water Erosion Control Practices

Treatment to control water erosion and surface water runoff consists of structural and vegetative practices that slow runoff water and capture contaminants that it may carry. Simulations of practices were added where needed (summarized in table 31) according to the following rules.

- **In-field mitigation:**
  - Terraces were added to all sample points with slopes greater than 6 percent, and to those with slopes greater than 4 percent *and* a high potential for excessive runoff (hydrologic soil groups C or D).

Although terraces may be too expensive or impractical to implement in all cases, they serve here as a surrogate for other practices that control surface water runoff.
- Contouring or stripcropping (overland flow practices) was added to all other fields with slope greater than 2 percent that did not already have those practices and did not have terraces.
- Concentrated flow practices were not applied since they occur on unique landscape situations within the field; landscape data other than slope and slope length were not available for CEAP sample points.

- **Edge-of-field mitigation:**
  - Fields adjacent to water received a riparian buffer, if one was not already present.
  - Fields not adjacent to water received a filter strip, if one was not already present.

In addition, the implementation of structural and vegetative practices is simulated by an adjustment in the land condition parameter used to estimate the NRCS Runoff Curve Number (RCN). The RCN is an empirical parameter used in surface hydrology for predicting direct runoff or infiltration. The hydrologic condition (a component in the determination of the RCN) was adjusted from “poor” to “good” for sample points where these additional practices were simulated.

Table 31. Summary of additional structural practices for water erosion control simulated for under-treated acres to assess the potential for gains from additional conservation treatment in the Ohio-Tennessee River Basin

	Critical under-treated acres (acres with a high level of treatment need)		Non-critical under-treated acres (acres with a moderate level of treatment need)		All under-treated acres	
Additional practice	Treated acres	Percent of total	Treated acres	Percent of total	Treated acres	Percent of total
Overland flow practice only	0	0	50,927	<1	50,927	<1
Terrace only	120,013	2	50,415	<1	170,428	1
Terrace plus overland flow practice	0	0	0	0	0	0
Filter only	1,200,721	20	5,719,890	50	6,920,611	40
Filter plus overland flow practice	770,382	13	1,042,390	9	1,812,772	10
Filter plus Terrace	2,328,939	39	846,144	7	3,175,083	18
Filter plus overland flow practice plus terrace	0	0	0	0	0	0
Buffer only	693,649	12	2,453,941	21	3,147,589	18
Buffer plus overland flow practice	213,051	4	420,776	4	633,827	4
Buffer plus Terrace	510,104	8	248,683	2	758,787	4
Buffer plus overland flow practice plus terrace	0	0	0	0	0	0
One or more additional practices	5,836,859	97	10,833,165	94	16,670,025	95
No structural practices	175,426	3	672,495	6	847,921	5
Total	6,012,285	100	11,505,660	100	17,517,945	100

Note: Percents may not add to totals because of rounding.

Simulation of Additional Nutrient Management Practices

The nutrient management treatment scenario consists of additional nutrient management practices where needed *in addition to* the erosion control practices. The nutrient management practices simulated the application of nutrients at an appropriate rate, in an appropriate form, at appropriate times, and using an appropriate method of application to provide sufficient nutrients for crop growth while minimizing losses to the environment. Simulation of nutrient management required changes to nutrient applications for one or more crops on all but about 7 percent of the acres (see table 9).

Specific rules for application timing

The goal for appropriate timing is to apply nutrients close to the time when the plant is likely to require them, thereby minimizing the opportunity for loss from the field. Rules for the timing of nutrient applications (both nitrogen and phosphorus) are:

- All commercial fertilizer applications were adjusted to 14 days prior to planting, except for acres susceptible to leaching loss.
- For acres susceptible to leaching loss (hydrologic soil group A, soils with sandy textures, or tile drained fields), nitrogen was applied in split applications, with 25 percent of the total application 14 days before planting and 75 percent 30 days after planting.
- Manure applications during winter months (December, January, February, and March) were moved to 14 days pre-plant or April 1, whichever occurs first. This rule allows for late March applications of manure in the warmer climates of the Ohio-Tennessee River Basin. April 1 is near the period when the soils warm and become biologically active. However, this late date could begin to pressure manure storage capacities and it is recognized that this could create storage problems.

In the baseline condition, about 25 percent of the cropped acres in the Ohio-Tennessee River Basin receive fertilizer applications in the fall for at least one spring-planted row crop in the rotation. The only fall application of nutrients simulated in the nutrient management treatment scenario was for fall seeded crops that received a starter fertilizer at planting time.

Specific rules for method of application

If the method of application was other than incorporation then in the simulations fertilizer and manure applications became incorporated or injected. Incorporation reduces the opportunity for nutrients on the soil surface to volatize or be carried away in soluble form or attached to eroding particles. For manure applications on no-till fields, if the manure was in liquid or slurry form and had been sprayed/broadcast applied it was changed to injected or placed under the soil surface. Manure of solid consistency was incorporated by disking without regard to the tillage management type. If the tillage type had been originally no-till, the incorporation of the manure changed the tillage type to mulch tillage.

Specific rules for the form of application

If the tillage type was no-till, commercial fertilizer was changed to a form that could be knifed or injected below the soil surface. The change in form did not change the ammonia or nitrate ratio of the fertilizer.

Specific rules for the rate of nutrient applied

Nitrogen application rates above 1.2 times the crop removal rate were reduced in the simulations to 1.2 times the crop removal rate for all crops except cotton and small grain crops. The 1.2 ratio is in the range of rates recommended by many of the Land Grant Universities. This rate accounts for the savings in nutrients due to improved application timing and implementation of water erosion control practices and also replaces a reduced amount of environmental losses that occur during the cropping season.

For small grain crops (wheat, barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale), nitrogen applications above 1.5 times the crop removal rate were reduced to 1.5 times the crop removal rate. For cotton, nitrogen applications were reduced to 50 pounds per bale for sample points with application rates exceeding 50 pounds per bale.

Phosphorus application rates above 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation were adjusted to be equal to 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation. Application rates for all phosphorus applications in the rotation were reduced in equal proportions.

Potential for Field-Level Gains

Treatment of the 6.0 million critical under-treated acres

According to the model simulation, treatment of the 6.0 million critical under-treated acres (acres with a “high” level of treatment need) with water erosion control practices would nearly eliminate sediment loss for these acres and dramatically reduce nitrogen and phosphorus lost to surface water, as shown in table 32. Sediment loss would be reduced to an annual average of about 0.3 ton per acre per year for these acres, a 94-percent reduction. Nitrogen loss with surface runoff would be reduced to 7.9 pounds per acre per year on average (69-percent reduction), and phosphorus lost to surface water would be reduced to 4.0 pounds per acre per year (48-percent reduction). However, the re-routing of surface water to subsurface flow pathways would *increase* nitrogen loss in subsurface flows by 3 percent, on average, for these acres.

The addition of nutrient management had little additional effect on sediment loss or nitrogen loss with surface runoff, but was effective in reducing nitrogen loss in subsurface flows and phosphorus lost to surface water (table 32). Nitrogen loss in subsurface flows for these acres would be reduced 49 percent compared to losses simulated for the baseline conservation condition. Phosphorus lost to surface water would be reduced 77 percent compared to the baseline

condition, bringing the average loss down to below 2 pounds per acre for these acres.

These results support the conclusion drawn from the assessment of the effects of conservation practices that nutrient management practices need to be paired with erosion control practices to obtain significant reductions in the loss of soluble nutrients.

Table 33 presents estimates of how treatment of only the 6.0 million critical under-treated acres in the region would reduce *overall* edge-of-field losses *for the region as a whole*. These results were obtained by combining treatment scenario model results for the 6.0 million acres with model results from the baseline conservation condition for the remaining acres.

Compared to the baseline conservation condition, treating the 6.0 million critical under-treated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole—

- reduce sediment loss in the region by 61 percent on average;
- reduce total nitrogen loss by 19 percent:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 34 percent, and
  - reduce nitrogen loss in subsurface flows by 15 percent;
- reduce phosphorus lost to surface water (sediment adsorbed and soluble) by 31 percent; and
- reduce environmental risk from loss of pesticide residues by 3 percent.

Treatment of all 17.5 million under-treated acres

Simulation results for all the 17.5 million under-treated acres (acres with either a "high" or "moderate" level of treatment need) are presented in table 34 and results for the region as a whole are presented in table 35.

Table 34 shows that per-acre percent reductions of sediment and nutrient loss due to additional practices would be less, on average, than percent reductions for the 6.0 million most vulnerable under-treated acres. The 17.5 million under-treated acres include 11.5 million acres with a moderate need for treatment that are less vulnerable or have more conservation practice use than the critical under-treated acres and therefore the potential for gains with additional treatment is less for those acres. The percent reductions *for the region as a whole* by treating 11.5 million additional acres, however, would be much higher, as shown in table 35.

Compared to the baseline conservation condition, treating all 17.5 million under-treated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole (table 35)—

- reduce sediment loss in the region by 83 percent on average;
- reduce total nitrogen loss by 40 percent:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 58 percent, and
  - reduce nitrogen loss in subsurface flows by 37 percent;
- reduce phosphorus lost to surface water by 62 percent; and
- reduce environmental risk from loss of pesticide residues by 11 percent.

Emerging Technologies for Reducing Nutrient Losses from Farm Fields

The nutrient management simulated to assess the potential for further gains from conservation treatment represents traditional nutrient management techniques that have been in use for several years and would be expected to be found in current NRCS conservation plans. There are, however, emerging conservation technologies that have the potential to further reduce nutrient loss from farm fields and provide even greater crop use efficiencies once the technologies become more widespread. These include—

- Innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies;
- Enhanced-efficiency nutrient application products such as slow or controlled release fertilizers, polymer coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- Drainage water management that controls discharge of drainage water and provides treatment of contaminants, thereby reducing the levels of nitrogen and even some soluble phosphorus loss; and
- Constructed wetlands receiving surface water runoff or drainage water from farm fields prior to discharge to streams and rivers.

New technologies that have the potential to increase crop yields without increasing nutrient inputs could further improve crop nutrient use efficiency and reduce offsite transport of nutrients relative to the level of crop production.

Table 32. Conservation practice effects for additional treatment of 6.0 million critical under-treated acres (acres with a *high* need for conservation treatment) in the Ohio-Tennessee River Basin

Model simulated outcome	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	8.3	7.4	10	7.5	10
Subsurface water flow (inches)	9.8	10.4	-6	10.6	-8
Erosion and sediment loss					
Wind erosion (tons/acre)	0.04	0.03	20	0.03	26
Sheet and rill erosion (tons/acre)	2.57	1.03	60	0.97	62
Sediment loss at edge of field due to water erosion (tons/acre)	4.27	0.27	94	0.26	94
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-103	-20	--	-15	--
Nitrogen					
Nitrogen applied (pounds/acre)	92	89*	3	65	29
Nitrogen in crop yield removed at harvest (pounds/acre)	104	103	2	99	5
Total nitrogen loss for all loss pathways (pounds/acre)	59.6	43.2	27	26.3	56
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	25.1	7.9	69	6.2	75
Nitrogen loss in subsurface flows (pounds/acre)	24.5	25.1	-3	12.6	49
Phosphorus					
Phosphorus applied (pounds/acre)	27.6	27.1*	2	18.9	31
Total phosphorus loss for all loss pathways (pounds/acre)	7.8	4.1	47	1.9	76
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	7.7	4.0	48	1.8	77
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	35.2	21.3	40	21.2	40
Surface water pesticide risk indicator for aquatic ecosystems	3.99	3.42	14	3.39	15
Surface water pesticide risk indicator for humans	0.89	0.77	14	0.76	15

* Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.

Note: Values reported in this table are for the 6.0 million critical under-treated acres only. Percent reductions are with respect to the baseline conservation condition.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 33. Conservation practice effects for the region as a whole* after additional treatment of 6.0 million critical under-treated acres (acres with a *high* need for conservation treatment) in the Ohio-Tennessee River Basin

	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
Model simulated outcome	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	7.6	7.4	3	7.4	3
Subsurface water flow (inches)	9.3	9.4	-2	9.5	-2
Erosion and sediment loss					
Wind erosion (tons/acre)	0.02	0.02	9	0.02	11
Sheet and rill erosion (tons/acre)	1.14	0.77	32	0.76	34
Sediment loss at edge of field due to water erosion (tons/acre)	1.59	0.63	60	0.63	61
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	27	47	--	48	--
Nitrogen					
Nitrogen applied (pounds/acre)	84	83**	1	77	8
Nitrogen in crop yield removed at harvest (pounds/acre)	114	114	0	113	1
Total nitrogen loss for all loss pathways (pounds/acre)	42.6	38.7	9	34.6	19
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	13.2	9.1	31	8.7	34
Nitrogen loss in subsurface flows (pounds/acre)	19.2	19.4	-1	16.4	15
Phosphorus					
Phosphorus applied (pounds/acre)	24.4	24.3**	1	22.3	9
Total phosphorus loss for all loss pathways (pounds/acre)	4.6	3.7	19	3.2	31
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	4.5	3.6	20	3.1	31
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	27.5	24.2	12	24.2	12
Surface water pesticide risk indicator for aquatic ecosystems	4.36	4.22	3	4.21	3
Surface water pesticide risk indicator for humans	0.93	0.90	3	0.90	3

* Results presented for the region as a whole combine model output for the 6.0 million treated acres with model results from the baseline conservation condition for the remaining acres.

** Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices.

Note: Percent reductions are with respect to the baseline conservation condition.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 34. Conservation practice effects for additional treatment of 17.5 million under-treated acres (acres with a *high* or *moderate* need for conservation treatment) in the Ohio-Tennessee River Basin

Model simulated outcome	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	7.8	7.0	10	7.0	10
Subsurface water flow (inches)	9.4	10.0	-6	10.1	-8
Erosion and sediment loss					
Wind erosion (tons/acre)	0.02	0.02	15	0.02	21
Sheet and rill erosion (tons/acre)	1.42	0.63	56	0.58	59
Sediment loss at edge of field due to water erosion (tons/acre)	2.05	0.17	92	0.16	92
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	5	49	--	52	--
Nitrogen					
Nitrogen applied (pounds/acre)	89	86*	3	64	28
Nitrogen in crop yield removed at harvest (pounds/acre)	113	110	3	107	6
Total nitrogen loss for all loss pathways (pounds/acre)	47.8	38.8	19	23.7	50
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	15.7	6.4	59	4.9	69
Nitrogen loss in subsurface flows (pounds/acre)	21.4	21.8	-2	11.1	48
Phosphorus					
Phosphorus applied (pounds/acre)	26.6	26.1*	2	19.5	27
Total phosphorus loss for all loss pathways (pounds/acre)	5.7	3.7	35	1.7	71
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	5.6	3.6	35	1.6	71
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	30.0	21.2	29	21.1	30
Surface water pesticide risk indicator for aquatic ecosystems	4.70	4.07	13	4.03	14
Surface water pesticide risk indicator for humans	0.98	0.84	14	0.84	15

* Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.

Note: Values reported in this table are for the 17.5 million under-treated acres only. Percent reductions are with respect to the baseline conservation condition.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 35. Conservation practice effects for the region as a whole* after additional treatment of 17.5 million under-treated acres (acres with a *high* or *moderate* need for conservation treatment) in the Ohio-Tennessee River Basin

Model simulated outcome	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	7.6	7.1	7	7.1	7
Subsurface water flow (inches)	9.3	9.7	-4	9.8	-6
Erosion and sediment loss					
Wind erosion (tons/acre)	0.02	0.02	11	0.02	17
Sheet and rill erosion (tons/acre)	1.14	0.59	49	0.55	52
Sediment loss at edge of field due to water erosion (tons/acre)	1.59	0.28	83	0.27	83
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	27	58	--	59	--
Nitrogen					
Nitrogen applied (pounds/acre)	84	82**	2	66	21
Nitrogen in crop yield removed at harvest (pounds/acre)	114	112	2	110	4
Total nitrogen loss for all loss pathways (pounds/acre)	42.6	36.3	15	25.8	40
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	13.2	6.7	49	5.6	58
Nitrogen loss in subsurface flows (pounds/acre)	19.2	19.5	-1	12.0	37
Phosphorus					
Phosphorus applied (pounds/acre)	24.4	24.1**	2	19.4	21
Total phosphorus loss for all loss pathways (pounds/acre)	4.6	3.2	30	1.8	61
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	4.5	3.1	31	1.7	62
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	27.5	21.4	22	21.3	23
Surface water pesticide risk indicator for aquatic ecosystems	4.36	3.91	10	3.89	11
Surface water pesticide risk indicator for humans	0.93	0.84	10	0.83	11

* Results presented for the region as a whole combine model output for the 17.5 million treated acres with model results from the baseline conservation condition for the remaining acres.
** Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.
Note: Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Comparison of treatment scenario results

The distributions of sediment and nutrient losses for the two levels of treatment are compared to the baseline conservation condition in the Ohio-Tennessee River Basin in figures 67 through 71. For perspective, the distribution of loss estimates if no conservation practices were in use, represented by the no-practice scenario, is also shown.

The distributions show how the number of acres with high losses could be reduced dramatically in the region, by treating the under-treated acres. For example, 18 percent of the acres in the Ohio-Tennessee River Basin exceed an annual average loss of sediment of 2 tons per acre per year in the baseline conservation condition. Model simulations indicate that treating the most critical under-treated acres (6.0 million acres) with water erosion control practices would reduce the acres exceeding sediment loss of 2 tons per acre per year to 5 percent (fig. 67). Expanding the treatment to include all under-treated acres (17.5 million acres) would further reduce the acres exceeding annual sediment loss of 2 tons per acre to 1 percent.

Treatment of critical under-treated acres with water erosion control *and* nutrient management would reduce the acres exceeding 15 pounds per acre of nitrogen lost with runoff from 25 percent for the baseline to 11 percent (fig. 68). Treatment of all 17.5 million under-treated acres would further reduce the percent losing more than 15 pounds per acre to 2 percent of cropped acres in the region.

For nitrogen loss in subsurface flow pathways, however, treatment of all 17.5 million under-treated acres would be required to reduce the overall regional edge-of-field losses to acceptable levels (fig. 69). About 20 percent of the acres in the region have nitrogen loss in subsurface flows greater than 25 pounds per acre per year for the baseline conservation condition. Treating the 6.0 million critical under-treated acres with nutrient management practices would reduce this percentage to 13 percent. Treatment of all 17.5 million under-treated acres would reduce the percentage to 5 percent.

For total nitrogen loss to all pathways, 41 percent of the acres in the baseline conservation condition exceed losses of 40 pounds per acre per year. Treating the most critical under-treated acres would reduce the acres exceeding this level of loss to 25 percent (fig. 70). Expanding the treatment to include all under-treated acres would further reduce the acres exceeding 40 pounds per acre to 8 percent.

Acres exceeding 4 pounds per acre of phosphorus lost to surface water would be reduced from 35 percent for the baseline to 20 percent by treating the critical acres and to 5 percent by treating all under-treated acres (fig. 71).

Soil organic carbon would be minimally affected by the additional soil erosion control and nutrient management practices. Increases in soil organic carbon would occur largely because of savings of carbon that would otherwise be lost from the field through wind and water erosion. Figure 72 shows that the percentage of acres building soil organic carbon would increase from 66 percent for the baseline conservation condition to 77 percent with additional conservation treatment of all the under-treated acres.

One of the objectives in constructing the treatment scenarios was to maintain the level of regional crop production. The removal of nitrogen at harvest serves as a useful proxy for crop yields and allows for aggregation over the mix of crops. The average annual amount of nitrogen removed at harvest would be reduced about 6 percent for the 17.5 million acres treated with additional soil erosion control and nutrient management practices (table 34), which represents a 4-percent reduction for the region as a whole (table 35). Figure 73 shows that the distribution of nitrogen removed at harvest would be slightly lower for the treatment scenario with nutrient management, but otherwise similar to the distribution for the baseline conservation condition.

Figure 67. Estimates of average annual sediment loss for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Ohio-Tennessee River Basin

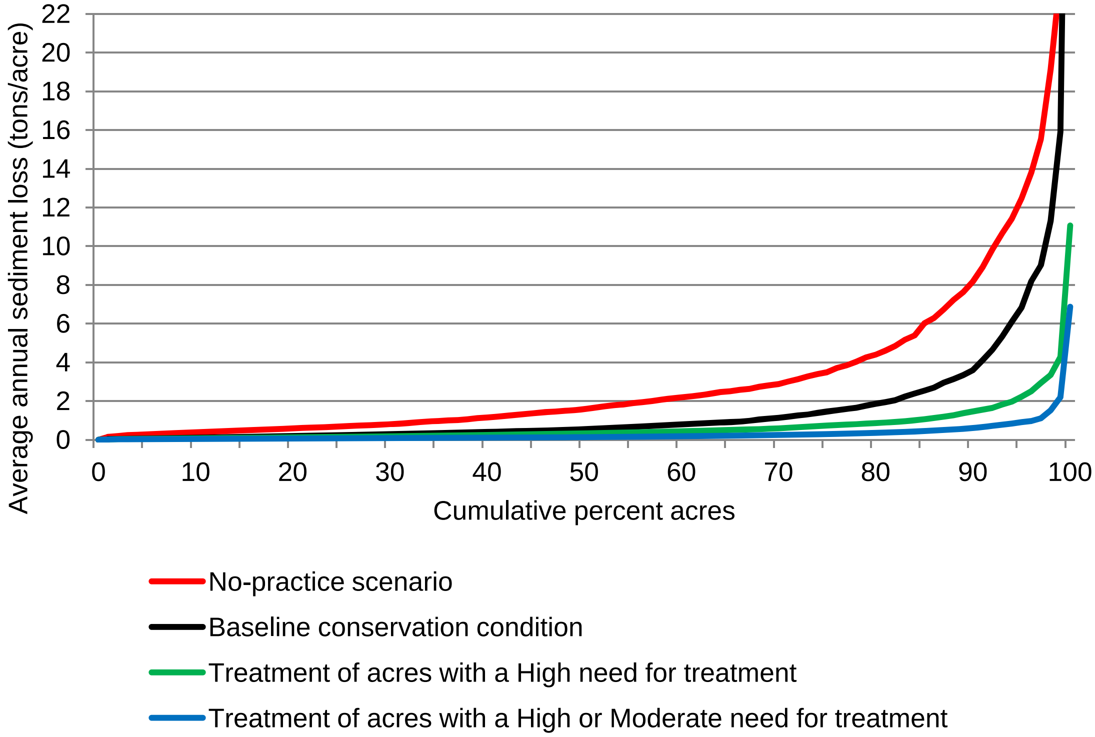


Figure 68. Estimates of average annual loss of nitrogen with surface runoff for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Ohio-Tennessee River Basin

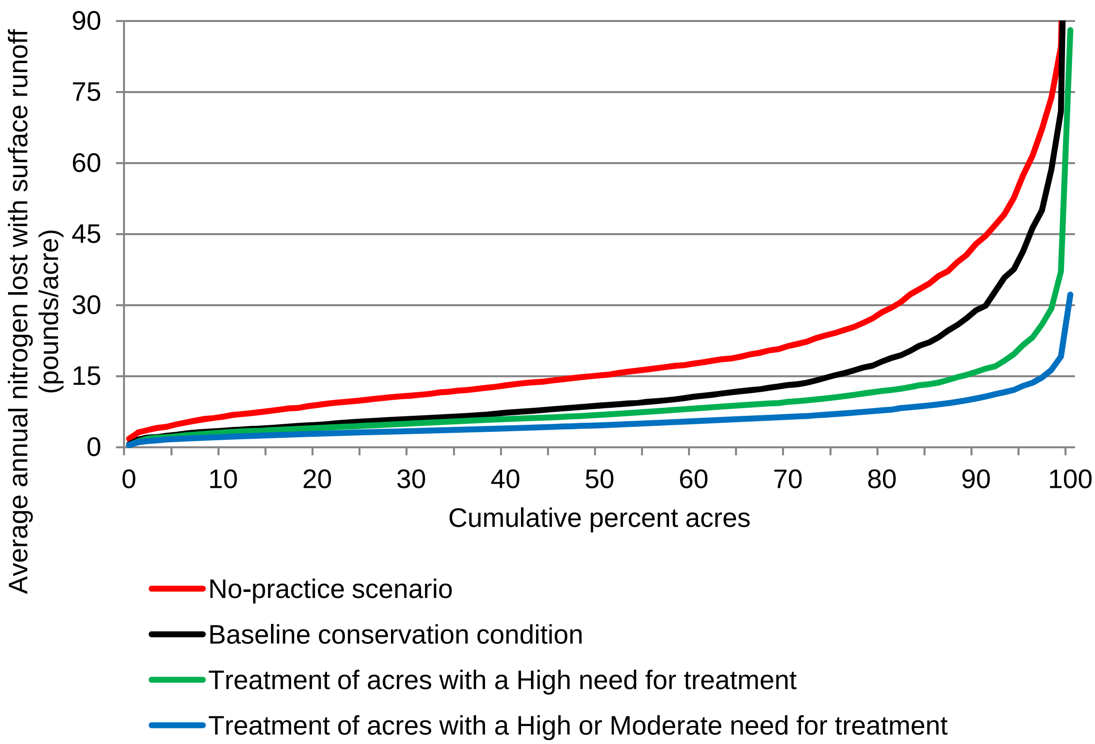


Figure 69. Estimates of average annual loss of nitrogen in subsurface flows for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Ohio-Tennessee River Basin

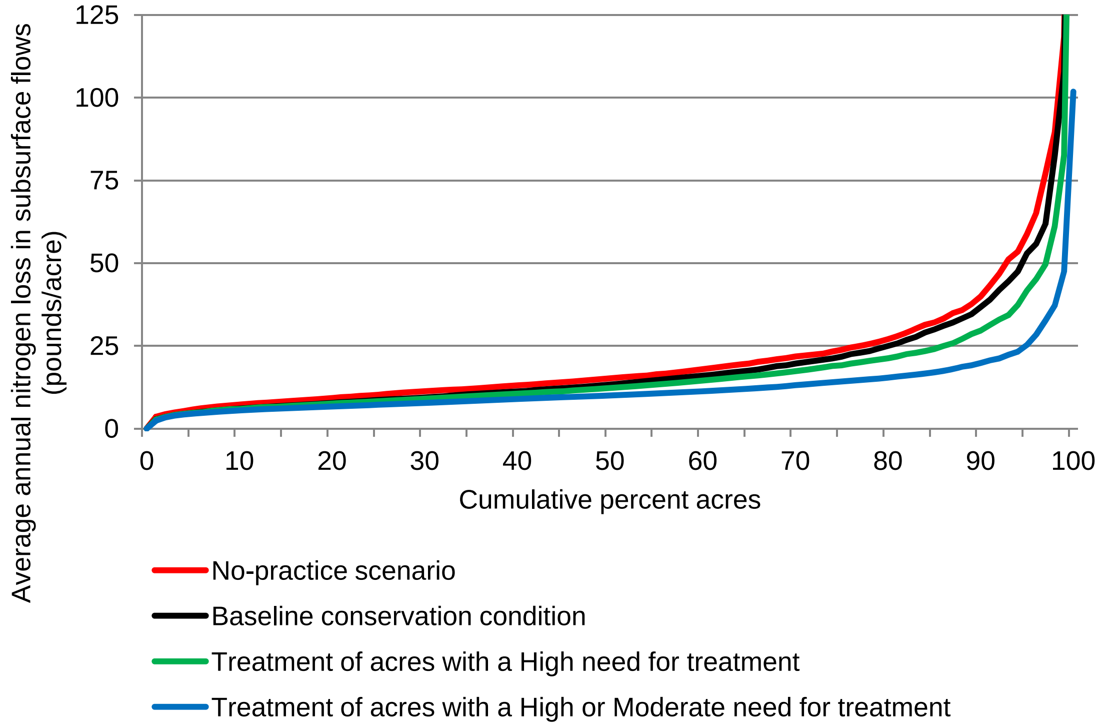


Figure 70. Estimates of average annual total nitrogen loss for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Ohio-Tennessee River Basin

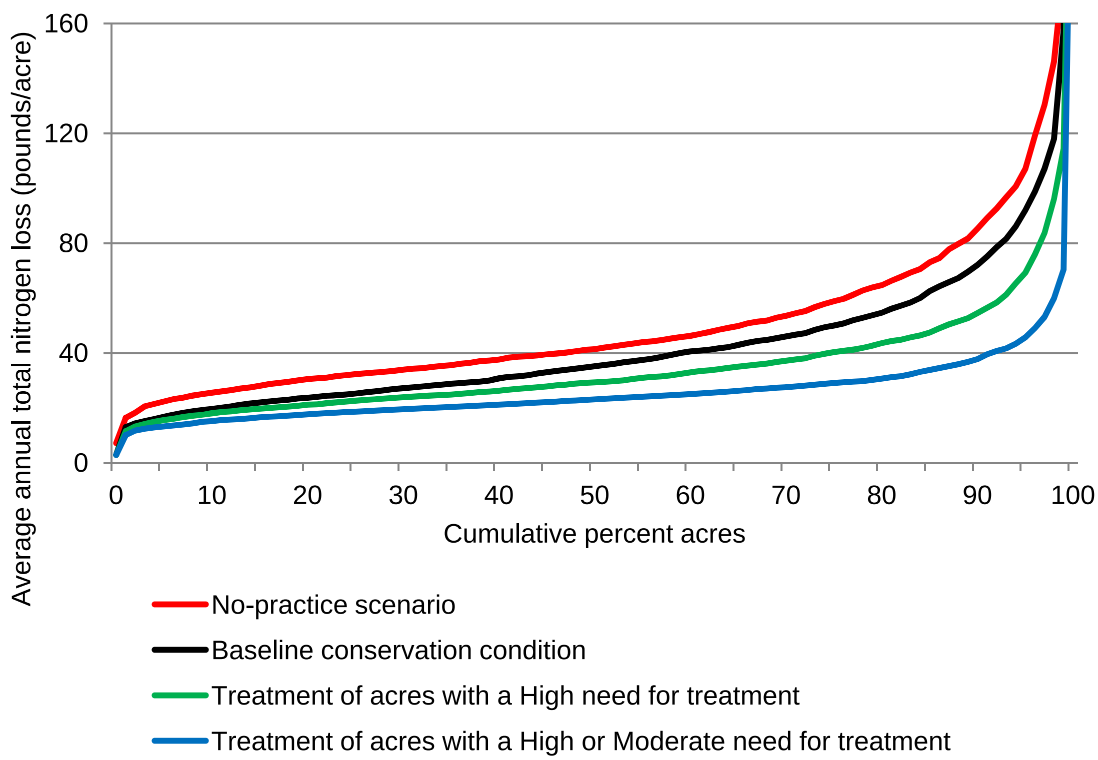
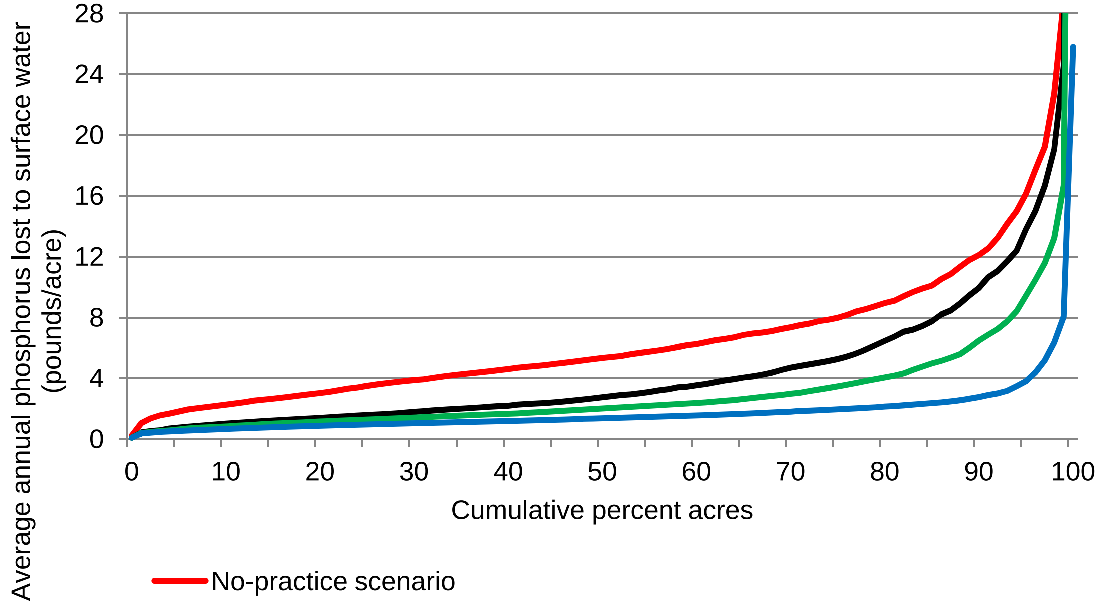


Figure 71. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Ohio-Tennessee River Basin



* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Figure 72. Estimates of average annual change in soil organic carbon for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Ohio-Tennessee River Basin

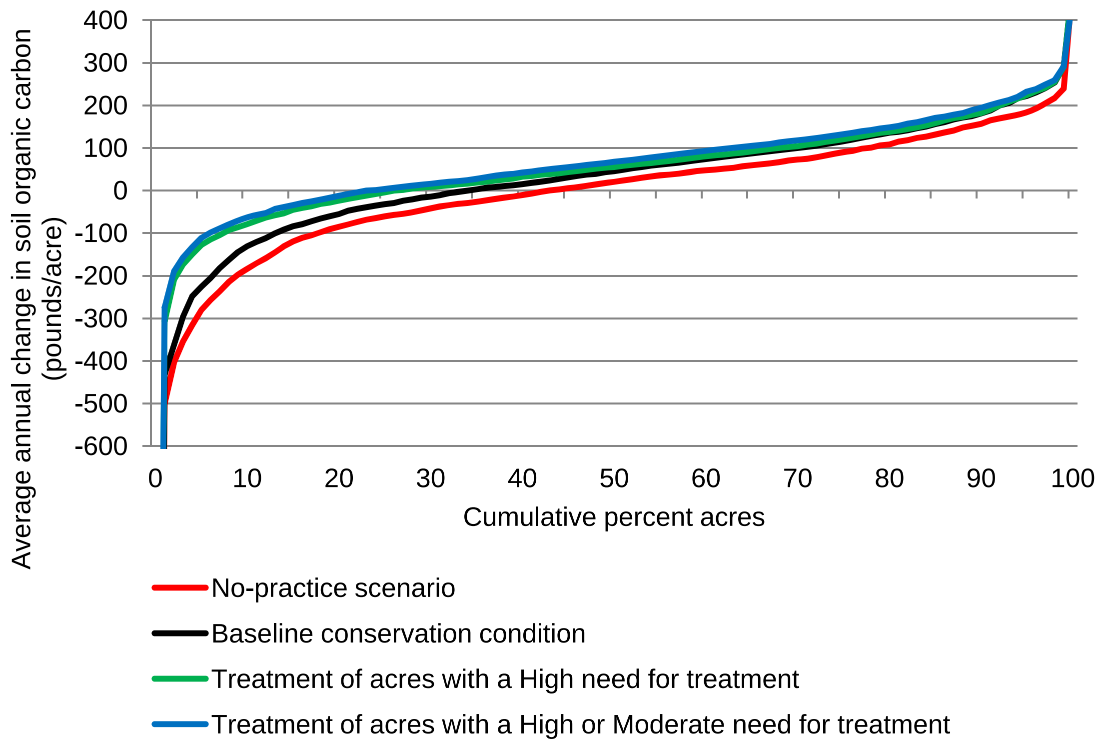
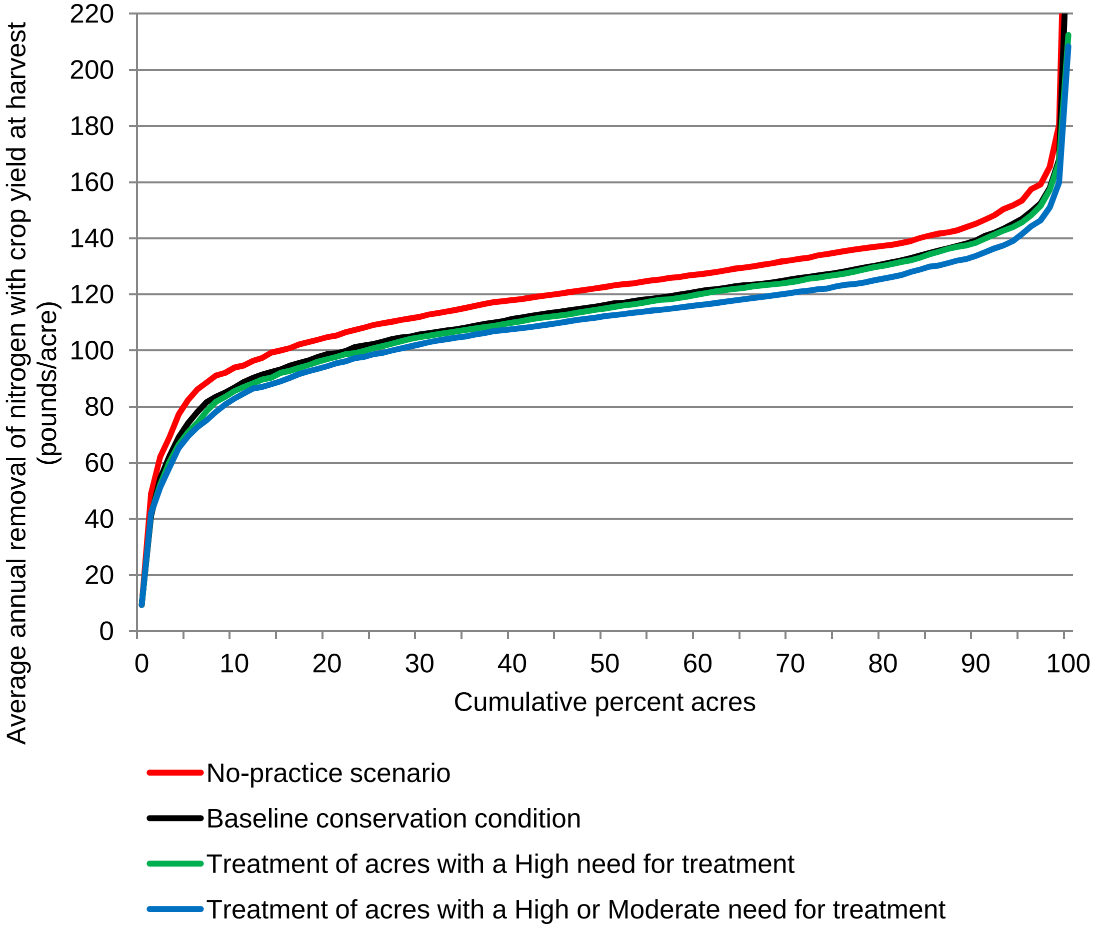


Figure 73. Estimates of average annual removal of nitrogen with crop yield at harvest for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Ohio-Tennessee River Basin



Diminishing returns from additional conservation treatment

Tables 32 through 35 and figures 67 through 71 suggest diminishing returns from additional conservation treatment when the most vulnerable acres are treated first. These diminishing returns are shown explicitly in table 36, which includes estimates of the effects of additional conservation practices on the 7.5 million adequately treated acres in the Ohio-Tennessee River Basin. Diminishing returns to additional conservation treatment is demonstrated by comparing the average annual per-acre reductions in loss among the three groups of acres.

For example, conservation treatment of the 6.0 million critical under-treated acres would reduce sediment loss an average of 4 tons per acre per year on those acres. In comparison, additional treatment of the 11.5 million under-treated acres with a moderate need for treatment would reduce sediment loss by about 0.77 ton per acre per year on those acres, and treatment of the remaining 7.5 million acres would reduce sediment loss by only 0.42 ton per acre per year on those acres, on average.

Similarly, diminishing returns were pronounced for nitrogen and phosphorus loss. Total nitrogen loss would be reduced by an average of 33 pounds per acre per year on the 6.0 million critical under-treated acres, compared to a reduction of 19 pounds per acre for the 11.5 million under-treated acres with a moderate need for treatment, and only 10 pounds per acre for the remaining 7.5 million acres.

Nitrogen loss in subsurface flows would be reduced by an average of 12 pounds per acre per year on the 6.0 million critical under-treated acres, compared to a reduction of 9.5 pounds per acre for the 11.5 million under-treated acres with a moderate need for treatment. The reduction for treatment of the remaining 7.5 million acres would average only 4.6 pounds per acre.

Total phosphorus loss would be reduced by an average of 5.9 pounds per acre per year on the 6.0 million critical under-treated acres, compared to a reduction of 3.0 pounds per acre for the 11.5 million under-treated acres with a moderate need for treatment and only 0.8 pound per acre for the remaining 7.5 million acres.

Some diminishing returns for reduction in environmental risk for pesticides are also evident, in spite of the fact that pesticide risk was not taken into account in the identification of under-treated acres and the assessment of conservation treatment needs.

(This rudimentary assessment of diminishing returns ignores the cost of treatment and is focused only on reducing edge-of-field losses. If the cost of treatment for the critical under-treated acres is substantially greater than the non-critical under-treated acres, the optimal strategy would be to treat a mix of critical and non-critical under-treated acres so as to maximize total edge-of-field savings for a given level of expenditure. If the objective of the conservation treatment was specifically to protect water quality, the relative environmental benefits of sediment and nutrient reductions would need to also be considered, as well as any edge-of-field loss thresholds that would need to be met to achieve local water quality goals.)

Estimates of edge-of-field sediment and nutrient savings due to use of conservation practices

A convenient way to envision the potential gains from further conservation treatment is to contrast the potential sediment and nutrient savings to estimated savings for the conservation practices currently in use.

The no-practice scenario represents the maximum losses that would be expected without any conservation practices in use. Treatment of *all acres* with nutrient management and erosion control practices was used to represent a "full-treatment" condition.

The difference in sediment and nutrient loss between these two scenarios represents the maximum savings possible for conservation treatment, which totaled 78.7 million tons of sediment, 355,271 tons of nitrogen, and 66,953 tons of phosphorus for the Ohio-Tennessee River Basin (fig. 74).

For sediment loss, about 54 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition (fig. 74). Additional treatment of the 6.0 million critical under-treated acres would account for another 31 percent of the potential sediment savings. Treatment of the 11.5 million under-treated acres with a moderate need for treatment would account for about 11 percent of the potential savings. Treatment of the 7.5 million adequately treated acres would account for the last 4 percent of potential savings.

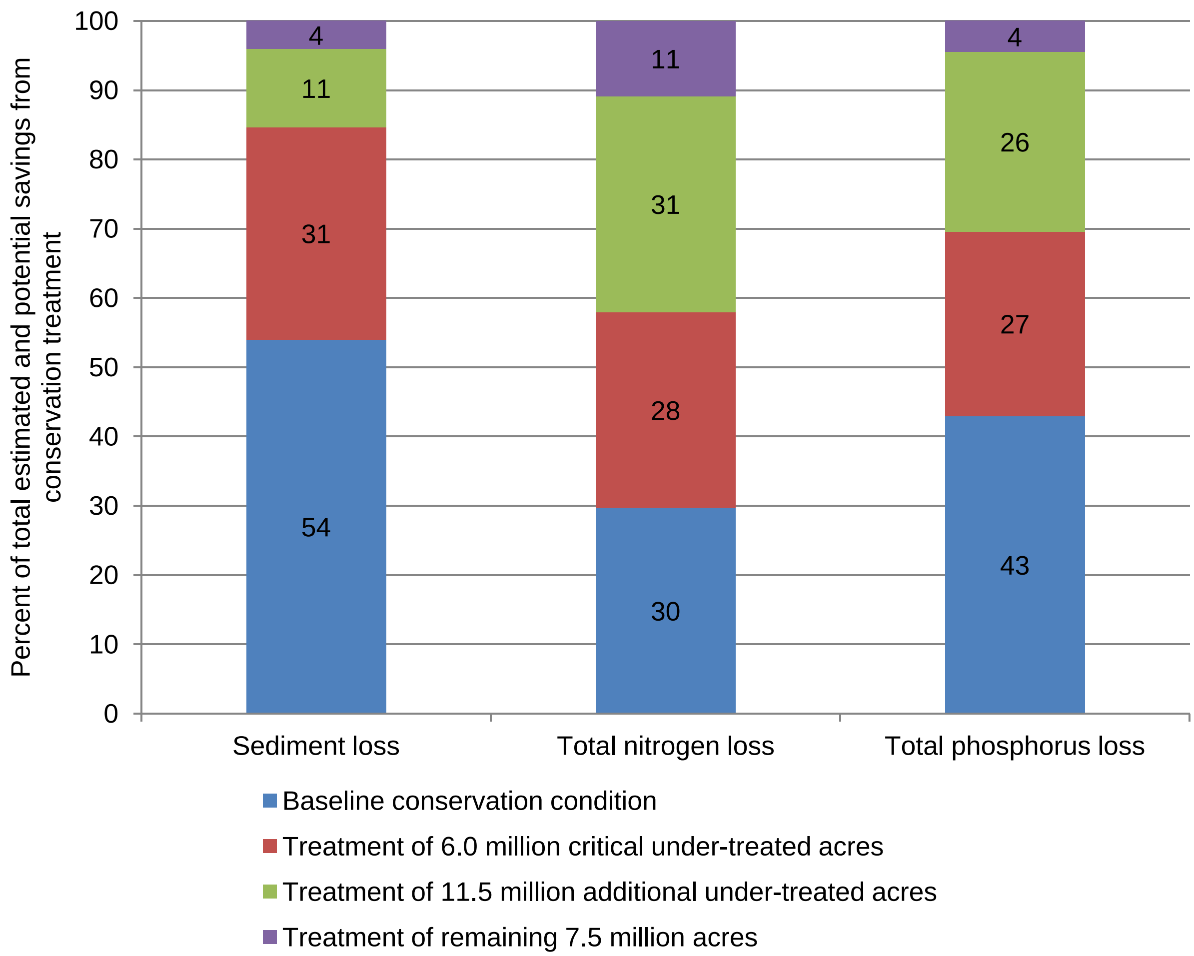
The proportions of savings from existing practices with additional conservation treatment are lower for nitrogen and phosphorus—30 and 43 percent, respectively—than for sediment loss. Correspondingly, there is more opportunity to reduce nitrogen and phosphorus losses with additional conservation treatment in this region (fig. 74).

Table 36. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices for three groups of acres comprising the 25.0 million cropped acres in the Ohio-Tennessee River Basin

	Additional treatment for 6.0 million critical under-treated acres*			Additional treatment for 11.5 million non-critical under-treated acres*			Additional treatment for remaining 7.5 million acres		
	Baseline	Treatment scenario		Baseline	Treatment scenario		Baseline	Treatment scenario	
	Average annual amount	Average annual amount	Reduction	Average annual amount	Average annual amount	Reduction	Average annual amount	Average annual amount	Reduction
Water flow									
Surface water runoff (inches)	8.3	7.5	0.8	7.5	6.8	0.7	7.2	6.5	0.7
Subsurface water flow (inches)	9.8	10.6	-0.8	9.1	9.9	-0.7	9.1	9.9	-0.8
Erosion and sediment loss									
Wind erosion (tons/acre)	0.04	0.03	0.009	0.02	0.01	0.002	0.02	0.01	0.003
Sheet and rill erosion (tons/acre)	2.57	0.97	1.61	0.82	0.38	0.44	0.49	0.25	0.24
Sediment loss at edge of field due to water erosion (tons/acre)	4.27	0.26	4.01	0.89	0.12	0.77	0.52	0.10	0.42
Soil organic carbon									
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-103	-15	88**	62	87	25**	78	97	19**
Nitrogen									
Nitrogen applied (pounds/acre)	92	65	27	87	63	24	72	58	14
Nitrogen in crop yield removed at harvest (pounds/acre)	104	99	5	118	110	7	117	111	6
Total nitrogen loss for all loss pathways (pounds/acre)	59.6	26.3	33.4	41.6	22.3	19.3	30.6	20.3	10.2
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	25.1	6.2	18.9	10.8	4.1	6.7	7.3	3.6	3.8
Nitrogen loss in subsurface flows (pounds/acre)	24.5	12.6	11.9	19.9	10.4	9.5	14.1	9.6	4.6
Phosphorus									
Phosphorus applied (pounds/acre)	27.60	18.92	8.68	26.14	19.75	6.39	19.26	17.62	1.64
Total phosphorus loss for all loss pathways (pounds/acre)	7.82	1.88	5.94	4.59	1.57	3.02	1.99	1.19	0.80
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	7.72	1.80	5.92	4.53	1.52	3.01	1.94	1.15	0.79
Pesticide loss									
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	35.2	21.2	14.0	27.3	21.1	6.2	21.8	17.8	4.0
Surface water pesticide risk indicator for aquatic ecosystem	3.99	3.39	0.59	5.07	4.36	0.71	3.56	3.07	0.49
Surface water pesticide risk indicator for humans	0.89	0.76	0.13	1.02	0.88	0.15	0.81	0.71	0.11

*Critical under-treated acres have a high need for additional treatment. Non-critical under-treated acres have a moderate need for additional treatment.
** Gain in soil organic carbon.

Figure 74. Comparison of estimated sediment, nitrogen, and phosphorus savings (field-level) that are due to practices in use in the baseline conservation condition and potential savings with additional water erosion control *and* nutrient management treatment of cropped acres in the Ohio-Tennessee River Basin



Tons of sediment, nitrogen, and phosphorus saved or potentially saved due to conservation practices

	Estimated savings due to conservation practice use (baseline conservation condition)	Potential savings from treatment of 6.0 million critical under-treated acres*	Potential savings from treatment of 11.5 million additional under-treated acres*	Potential savings from treatment of remaining 7.5 million acres*	Total estimated and potential savings from conservation treatment
Sediment	42,498,580	24,121,271	8,881,181	3,192,755	78,693,787
Nitrogen	105,567	100,346	110,821	38,537	355,271
Phosphorus	28,761	17,849	17,346	2,997	66,953

*Treatment with erosion control practices and nutrient management practices on all acres.
Note: Calculations do not include land in long-term conserving cover.
Note: Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

Chapter 7
Offsite Water Quality Effects of Conservation Practices

Field-level losses of sediment, nutrients, and atrazine estimated using APEX were integrated into a large-scale water quality model to estimate the extent to which conservation practices reduce—

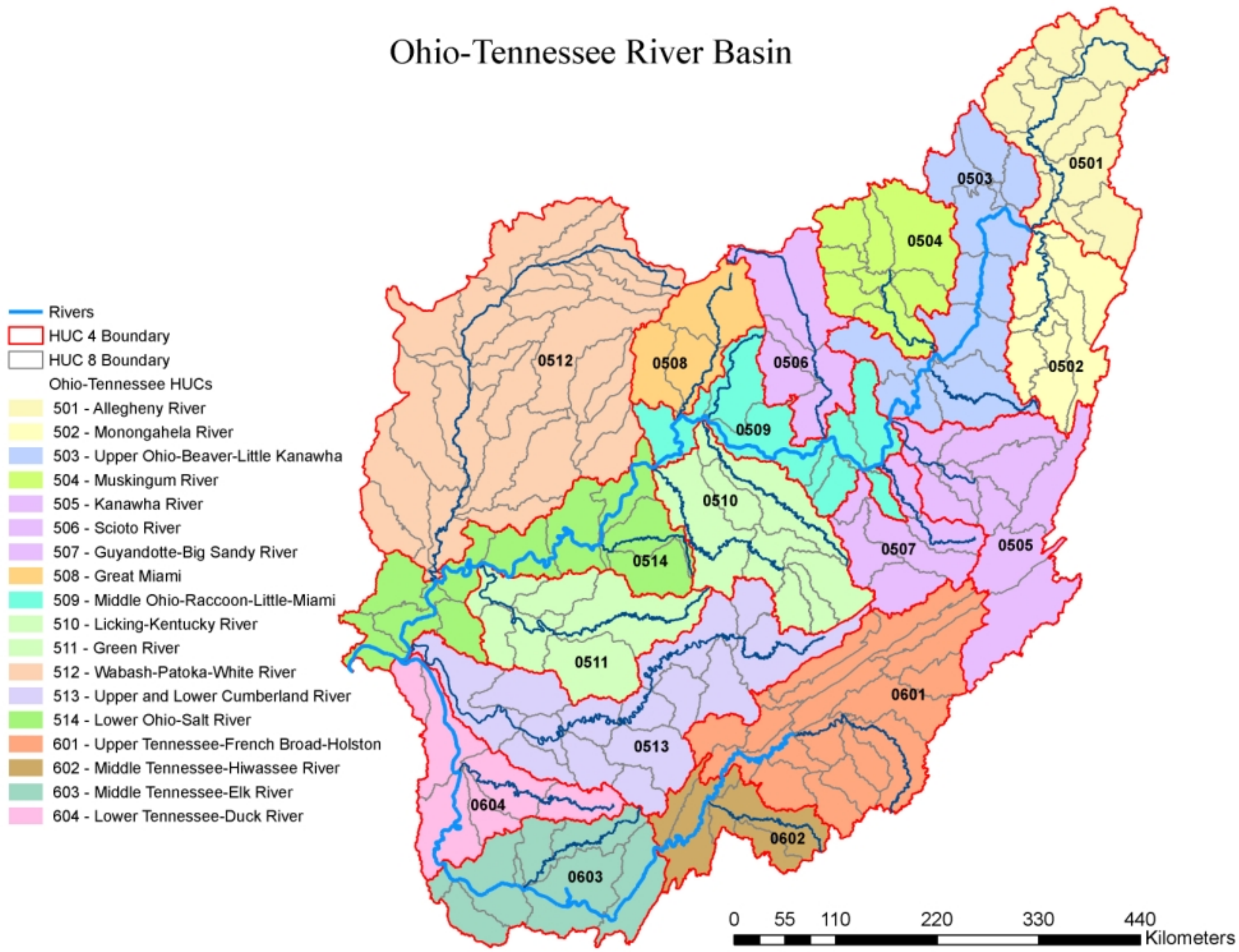
- loads delivered to rivers and streams within the basin,
- instream loads at various points within the basin, and
- loads exported from the region to the Mississippi River.

Loading estimates are generally reported for each of the subregions (4-digit hydrologic unit code), shown in figure 75. However, results for subregions with few acres of cultivated cropland are aggregated with other subregions for reporting because the CEAP sample had too few observations to report results separately.

Aggregated results are reported for 10 of the 18 subregions, as shown in the table below:

Aggregation used for reporting	Subregion code
Ohio River Basin	
Allegheny and Monongahela River subregions	
Allegheny River suberegion	0501
Monongahela River dubregion	0502
Scioto, Kanawha, and Guyandotte-Big Sandy River subregionss	
Kanawha River subregion	0505
Scioto River subregion	0506
Guyandotte-Big Sandy River subregion	0507
Licking-Kentucky and Green River subregion s	
Licking-Kentucky River subregion	0510
Green River subregion	0511
Tennessee River Basin	
Upper and Middle Tennessee River subregion s	
Upper Tennessee including French Broad-Holston subregion	601
Middle Tennessee including Hiwassee River subregion	602
Middle Tennessee including Elk River subregion	603

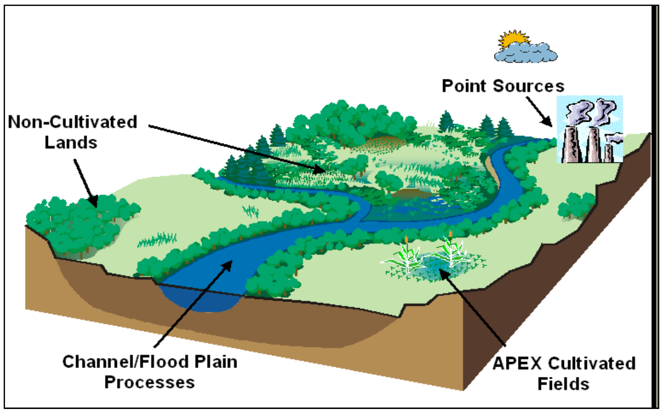
Figure 75. Subregions and 8-digit HUC groups used for reporting of source loads and instream loads for the 18 subregions in the Ohio-Tennessee River Basin



The National Water Quality Model—HUMUS/SWAT

Offsite estimates of water quality benefits were assessed using HUMUS/SWAT, a combination of the SWAT model and HUMUS (Hydrologic Unit Modeling for the United States) databases required to run SWAT at the watershed scale for all watersheds in the United States (Arnold et al. 1999; Srinivasan et al. 1998). SWAT simulates the transport of water, sediment, pesticides, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans (fig. 76).

Figure 76. Sources of water flows, sediment, and agricultural chemicals simulated with HUMUS/SWAT



Like APEX, SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007).[24] The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

Upland processes

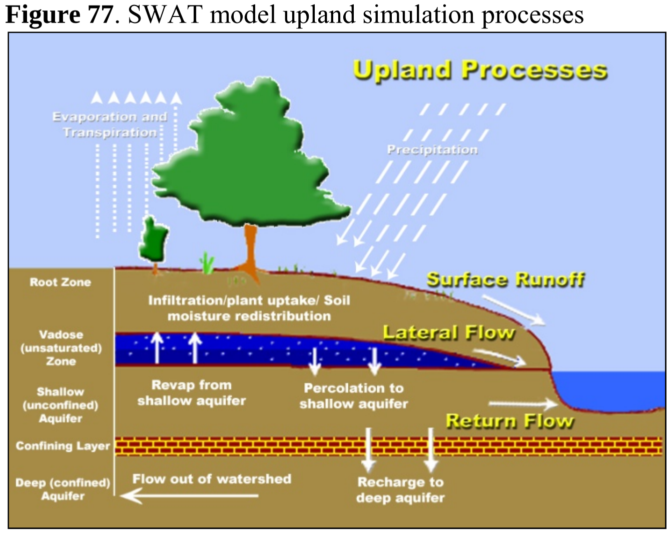
The water balance is the driving force for transport and delivery of sediment, nutrients, and pesticides from fields to streams and rivers. For this study, upland processes for non-cultivated cropland were modeled using SWAT, while source loads for cultivated cropland are estimated by APEX.

In SWAT, each watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, management, and slope. An HRU is not a contiguous land area, but rather represents the percentage of the watershed that has the HRU characteristics. In this study, SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides for the following land use categories, referred to as HRUs:

- Pastureland
- Permanent hayland
- Range shrub
- Range grass
- Urban
- Mixed forest
- Deciduous forest
- Evergreen forest
- Horticultural lands
- Forested wetlands
- Non-forested wetlands

Upland processes were modeled for each of these HRUs in each watershed (8-digit HUC) (fig. 77). The model simulates surface runoff estimated from daily rainfall; percolation modeled with a layered storage routing technique combined with a subsurface flow model; lateral subsurface flow; groundwater flow to streams from shallow aquifers, potential evapotranspiration; snowmelt; transmission losses from streams; and water storage and losses from ponds.

Figure 77. SWAT model upland simulation processes



Upland processes for cultivated cropland (including land in long-term conserving cover) were modeled using APEX as described in previous chapters. The weighted average of per-acre APEX model output for surface water delivery, sediment, nutrients, and pesticides was multiplied by the acres of cultivated cropland in the HUMUS database and used as SWAT model inputs for cultivated cropland for each 8-digit Hydrologic Unit Code (HUC). The acreage weights for the CEAP sample points were used to calculate the per-acre loads. (Several of the 8-digit watersheds in each region had too few CEAP sample points to reliably estimate edge-of-field per-acre loads. In these cases, the 6-digit per acre loads and sometimes the 4-digit per-acre loads were used to represent cultivated cropland.)

Various types of agricultural land management activities were modeled in SWAT. For permanent hayland, the following management activities were simulated:

[24] A complete description of the SWAT model can be found at http://www.brc.tamus.edu/swat/index.html.

- Hay was fertilized with nitrogen according to the crop need as determined by an auto-fertilization routine, which was set to grow the crop without undue nitrogen stress.
- Legume hay was grown in a 4-year rotation and phosphorus was applied at the time of planting (every fourth year) at a rate of 50 pounds per acre, followed by applications of 13 pounds per acre every other year.
- Manure was applied to hayland at rates estimated from probable land application of manure from animal feeding operations, estimated using the methods described in USDA/NRCS (2003).
- Three hay cuttings were simulated per crop year for grass hay and four hay cuttings were simulated per year for legume hay.
- For hayland acres that land-use databases indicated were irrigated, water was applied at a frequency and rate defined by an auto-irrigation routine.

For pastureland and rangeland, the following management activities were simulated:

- Continuous grazing was simulated by algorithms that determined the length of the grazing period, amount of biomass removed, and the amount of biomass trampled. Grazing occurs whenever the plant biomass is above a specified minimum plant biomass for grazing. The amount of biomass trampled daily is converted to residue.
- Manure nutrients from grazing animals were simulated for pastureland according to the density of pastured livestock as reported in the 2002 Census of Agriculture. Non-recoverable manure was estimated by subtracting recoverable manure available for land application from the total manure nutrients representing all livestock populations. Non-recoverable manure nutrients include the non-recoverable portion from animal feeding operations. Estimates of manure nutrients were derived from data on livestock populations as reported in the 2002 Census of Agriculture, which were available for each 6-digit HUC and distributed among the 8-digit HUCs on a per-acre basis.
- Manure was applied to pastureland and rangeland at rates estimated from probable land application of manure obtained from animal feeding operations as estimated in USDA/NRCS (2003).
- Supplemental commercial nitrogen fertilizers were applied to pastureland according to the crop need as determined by an auto-fertilization routine, which was set to grow grass without undue nitrogen stress.
- Land application of biosolids from wastewater treatment facilities was not simulated.

Horticulture land was fertilized with 100 pounds per acre of nitrogen per year and 44 pounds per acre of phosphorus. For the irrigated horticultural acres, water was applied at a frequency and rate defined by an auto-irrigation routine.

Land application of biosolids from wastewater treatment facilities was not simulated. Manure nutrients from wildlife populations are not included in the model simulation.

A summary of the total amount of nitrogen and phosphorus applied to agricultural land in the model simulation, including nitrogen and phosphorus applied to cultivated cropland in the APEX modeling, is presented in table 37.[25]

Urban Sources

Urban sources include (1) loads from point sources discharged from industrial and municipal wastewater treatment plants and (2) loads from urban land runoff.

Discharges from industrial and municipal wastewater treatment plants can be major sources of nutrients and sediment in some watersheds. Point sources of water flow, total suspended sediment, total phosphorus, and Kjeldahl nitrogen were estimated using county-level data on population change to adjust 1980 estimates of point source loadings published by Resources for the Future (Gianessi and Peskin 1984) to the year 2000. The original Resources for the Future assessment covered 32,000 facilities, including industries, municipal wastewater treatment plants, and small sanitary waste facilities for the years 1977 to 1981. A GIS-based procedure was used to convert county data to the 8-digit HUC level. Point source loads are aggregated within each watershed and average annual loads input into SWAT at the watershed outlet.

Urban runoff is estimated separately for three categories of cover within an urban HRU: 1) Pervious surfaces such as lawns, golf courses, and gardens, 2) impervious surfaces hydraulically connected to drainage systems such as paved roads and paved streets draining to storm drains, and 3) impervious surfaces not hydraulically connected to drainage systems such as a house roof draining to a pervious yard that is not directly connected to drains (composite urban surface consisting of impervious roof surface and pervious yard surface).

Pervious surfaces are simulated in the same manner as other grass areas (such as pasture). Surface runoff from pervious surfaces is calculated using the curve number. Nitrogen fertilizer (40 pounds per acre per year) is applied on grassed urban area such as lawns and grassed roadsides using an auto-fertilizer routine to grow grass without undue nitrogen stress. The grass is considered irrigated as needed based on plant stress demand using an auto-irrigation routine.

[25] For information on how manure nutrients were calculated for use in HUMUS modeling, see “Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT Modeling,” available at: http://www.nrcs.usda.gov/technical/nri/ceap.

Table 37. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Ohio-Tennessee River Basin.

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
			Cultivated cropland			
Allegheny and Monongahela River subregions (codes 0501, 0502)	19,870	6,743	26,613	5,464	2,490	7,955
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	18,592	3,128	21,721	4,341	1,293	5,635
Muskingum River subregion (code 0504)	32,621	5,369	37,990	9,727	2,237	11,964
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	70,071	4,290	74,362	21,091	1,612	22,703
Great Miami subregion (code 0508)	66,251	6,661	72,912	18,252	2,282	20,534
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	35,929	942	36,872	11,981	205	12,187
Licking-Kentucky and Green River subregions (codes 0510, 0511)	57,472	3,602	61,074	16,298	1,104	17,401
Wabash-Patoka-White River subregion (code 0512)	496,873	20,605	517,479	144,678	8,368	153,047
Upper and Lower Cumberland River subregion (code 0513)	50,312	2,026	52,337	12,335	748	13,083
Lower Ohio-Salt River subregion (code 0514)	75,739	870	76,609	22,075	287	22,361
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	39,661	1,936	41,597	10,915	577	11,492
Lower Tennessee including Duck River subregion (code 0604)	14,279	1,959	16,238	4,203	360	4,563
Total	977,671	58,132	1,035,803	281,361	21,564	302,925
			Hayland			
Allegheny and Monongahela River subregions (codes 0501, 0502)	16,664	360	17,024	1,081	163	1,244
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	12,103	199	12,303	823	91	914
Muskingum River subregion (code 0504)	4,374	530	4,904	1,082	230	1,312
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	11,909	194	12,103	476	92	568
Great Miami subregion (code 0508)	701	92	792	358	42	400
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	7,772	115	7,887	281	55	337
Licking-Kentucky and Green River subregions (codes 0510, 0511)	43,108	803	43,911	806	399	1,205
Wabash-Patoka-White River subregion (code 0512)	5,828	521	6,349	823	250	1,073
Upper and Lower Cumberland River subregion (code 0513)	30,177	1,031	31,208	168	497	665
Lower Ohio-Salt River subregion (code 0514)	16,976	258	17,234	400	135	535
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	41,417	4,854	46,271	204	2,252	2,455
Lower Tennessee including Duck River subregion (code 0604)	10,779	555	11,334	24	265	289
Total	201,808	9,512	211,320	6,527	4,470	10,997
			Pastureland and rangeland			
Allegheny and Monongahela River subregions (codes 0501, 0502)	2,723	11,007	13,730	1,211	4,894	6,105
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	2,100	8,501	10,601	1,004	4,050	5,054
Muskingum River subregion (code 0504)	3,196	12,968	16,164	1,373	5,571	6,944
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	3,810	15,368	19,177	2,098	8,446	10,544
Great Miami subregion (code 0508)	1,417	5,732	7,148	588	2,378	2,965
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	1,671	6,741	8,412	901	3,627	4,528
Licking-Kentucky and Green River subregions (codes 0510, 0511)	11,447	46,078	57,525	6,683	26,860	33,543
Wabash-Patoka-White River subregion (code 0512)	6,056	24,496	30,552	2,637	10,670	13,307
Upper and Lower Cumberland River subregion (code 0513)	7,219	29,038	36,257	4,271	17,157	21,428
Lower Ohio-Salt River subregion (code 0514)	4,600	18,513	23,113	2,632	10,582	13,214
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	13,537	59,051	72,587	7,914	33,888	41,802
Lower Tennessee including Duck River subregion (code 0604)	2,830	11,394	14,223	1,667	6,701	8,368
Total	60,605	248,886	309,491	32,979	134,824	167,803

* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

Table 37--continued. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Ohio-Tennessee River Basin

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
			Horticulture			
Allegheny and Monongahela River subregions (codes 0501, 0502)	1,422	0	1,422	626	0	626
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	453	0	453	199	0	199
Muskingum River subregion (code 0504)	669	0	669	295	0	295
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	611	0	611	269	0	269
Great Miami subregion (code 0508)	359	0	359	158	0	158
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	347	0	347	153	0	153
Licking-Kentucky and Green River subregions (codes 0510, 0511)	350	0	350	154	0	154
Wabash-Patoka-White River subregion (code 0512)	720	0	720	317	0	317
Upper and Lower Cumberland River subregion (code 0513)	1,487	0	1,487	655	0	655
Lower Ohio-Salt River subregion (code 0514)	401	0	401	176	0	176
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	1,609	0	1,609	708	0	708
Lower Tennessee including Duck River subregion (code 0604)	211	0	211	93	0	93
Total	8,639	0	8,639	3,803	0	3,803
			Total for all agricultural land			
Allegheny and Monongahela River subregions (codes 0501, 0502)	40,679	18,110	58,789	8,383	7,546	15,929
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	33,249	11,828	45,078	6,367	5,434	11,802
Muskingum River subregion (code 0504)	40,860	18,867	59,727	12,477	8,038	20,515
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	86,402	19,852	106,253	23,933	10,151	34,084
Great Miami subregion (code 0508)	68,727	12,484	81,211	19,356	4,702	24,058
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	45,719	7,798	53,517	13,316	3,888	17,204
Licking-Kentucky and Green River subregions (codes 0510, 0511)	112,377	50,483	162,860	23,941	28,363	52,304
Wabash-Patoka-White River subregion (code 0512)	509,478	45,622	555,100	148,455	19,288	167,744
Upper and Lower Cumberland River subregion (code 0513)	89,195	32,095	121,290	17,429	18,402	35,831
Lower Ohio-Salt River subregion (code 0514)	97,715	19,642	117,357	25,284	11,004	36,287
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	96,223	65,841	162,065	19,741	36,717	56,458
Lower Tennessee including Duck River subregion (code 0604)	28,099	13,907	42,006	5,987	7,325	13,312
Total	1,248,723	316,530	1,565,254	324,669	160,858	485,528

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

For estimating surface water runoff from impervious urban areas, a runoff curve number of 98 was used for surfaces connected hydraulically to drainage systems. A composite runoff curve number was used for impervious surfaces not hydraulically connected to drainage systems. Sediment and nutrients carried with storm water runoff to streams and rivers were estimated using the build up-wash off algorithm developed by Huber and Dickinson (1988).

The concept behind the buildup-wash off algorithm is that over a period of time, dust, dirt and other constituents are built up on street surfaces during dry periods. During a storm event the materials are washed off. The built-up wash-off algorithms are developed from an EPA national urban water quality database that relates storm runoff loads to rainfall, drainage area and impervious area.

Sediment produced from construction sites was also simulated in SWAT. Construction areas were assumed to represent 3 percent of urban areas. Parameters in the soil input file were modified to produce surface runoff and sediment yield that mimicked the average sediment load from published studies on construction sites.

A summary of the total amount of nitrogen and phosphorus applied to non-agricultural land in the model simulation is presented in table 38.

Nutrients from septic systems were not included in the model simulations as data on locations of septic systems, populations using the septic systems, and types of septic systems were not available.

Atmospheric nitrogen deposition

Atmospheric deposition of nitrogen can be a significant component of the nitrogen balance. Nitrogen deposition data (loads and concentrations) were developed from the National Atmospheric Deposition Program/National Trends Network database (NAPD 2004). When a rainfall event occurs in the model simulation, the amount of rainfall is multiplied by the average ammonium and nitrate concentrations calculated for the watershed to account for wet deposition. An additional amount of ammonium and nitrate are added on a daily basis to account for dry deposition.

Routing and channel processes

SWAT simulates stream/channel processes including channel flood routing, channel sediment routing, nutrient and pesticide routing, and transformations modified from the QUAL2E model (fig. 78).

- **Flood routing**. As water flows downstream, some may be lost due to evaporation and transmission through the channel bed. Another potential loss is removal of water from the channel for agricultural or human use. Flow may be supplemented by rainfall directly on the channel and/or addition of water from point source discharges.

- **Sediment routing—deposition, bed degradation, and streambank erosion**. Sediment transport in the stream network is a function of two processes, deposition and degradation. SWAT computes deposition and degradation simultaneously within the reach. Deposition is based on the fall velocity of the sediment particles and the travel time through each stream. Stream power is used to predict bed and bank degradation; excess stream power results in degradation. Bed degradation and streambank erosion are based on the erodibility and vegetative cover of the bed or bank and the energy available to carry sediment (a function of depth, velocity and slope). The maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity. Available stream power is used to re-entrain loose and deposited material until all of the material is removed.[26]

- **Nutrient routing**. Nutrient transformations in the stream are controlled by the instream water quality component of the model. The model tracks nutrients dissolved in the stream and nutrients adsorbed to the sediment. Dissolved nutrients are transported with the water, while those adsorbed to sediments are deposited with the sediment on the bed of the channel.

- **Pesticide routing**. As with nutrients, the total pesticide load in the channel is partitioned into dissolved and sediment-attached components. While the dissolved pesticide is transported with water, the pesticide attached to sediment is affected by sediment transport and deposition processes. Pesticide transformations in the dissolved and adsorbed phases are governed by first-order decay relationships. The major instream processes simulated by the model are settling, burial, resuspension, volatilization, diffusion, and transformation.

Reservoirs alter the dynamics of a free-flowing river, resulting in different rates of sediment deposition and chemical transformations. SWAT includes routines for reservoirs that account for the hydrological aspects of reservoirs. Basic reservoir data such as storage capacity and surface area were obtained from the dams database.

- **Reservoir outflow**. A simple reservoir simulation approach was used in this study. It is a monthly target release-storage approach based on the storage capacity and flood seasons.

[26] There are no national estimates of stream bank erosion that can be uniformly used to calibrate this component of the model. Parameters governing instream sediment processes are adjusted in concert with those governing upland sediment yields such that HUMUS predictions at calibration sites mimic measured sediment data. Sediment data collected at a single stream gauging site is a combination of upland and instream sources, which cannot be proportioned by source. Collectively a network of sediment monitoring sites may be used to develop a sediment budget for a watershed which may include a stream bank component. When such studies are available for a HUMUS region they are used as ancillary data during model calibration.

- **Sediment routing**. The concentration of sediment in the reservoir is estimated using a simple continuity equation based on volume and concentration of inflow, outflow, and water retained in the reservoir. Settling of sediment in the reservoir is governed by an equilibrium sediment concentration and the median sediment particle size. The amount of sediment in the reservoir outflow is the product of the volume of water flowing out of the reservoir and the suspended sediment concentration in the reservoir at the time of release.

- **Reservoir nutrients**. The model assumes that (1) the reservoir is completely mixed, (2) phosphorus is the limiting nutrient, and (3) total phosphorus is a measure of the trophic status. The phosphorus mass balance equation includes the concentration in the reservoir, inflow, outflow, and overall loss rate.

Figure 78. SWAT model channel simulation processes

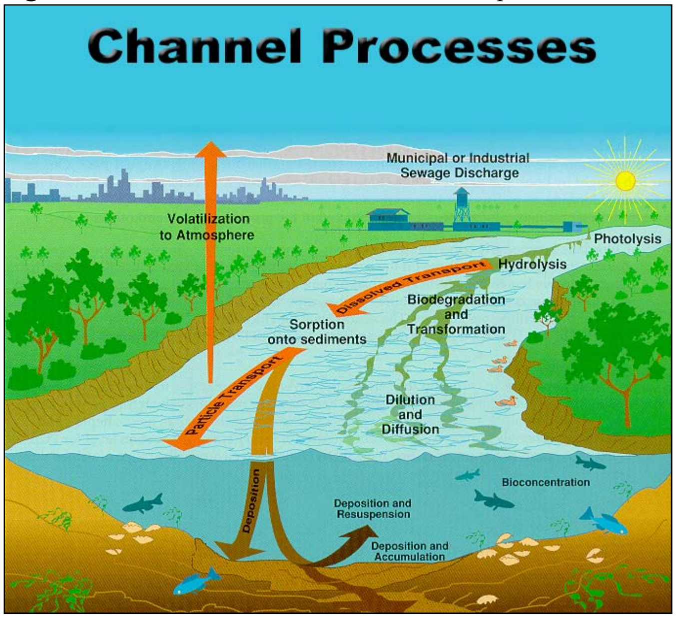


Table 38. Summary of nutrients applied to urban land, nutrients originating from point sources, and wet and dry atmospheric deposition of nitrogen used as inputs to the HUMUS/SWAT model, Ohio-Tennessee River Basin.

	Urban land	Point sources		Wet and dry atmospheric deposition
Subregion	Nitrogen fertilizer (tons/year)	Nitrogen (tons/year)	Phosphorus (tons/year)	Nitrogen (tons/year)
Allegheny and Monongahela River subregions (codes 0501, 0502)	9,843	11,982	1,566	54,203
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	10,025	13,615	1,458	36,491
Muskingum River subregion (code 0504)	5,578	3,507	770	17,454
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	12,508	4,884	1,044	55,380
Great Miami subregion (code 0508)	5,174	2,549	671	5,834
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	6,209	2,107	464	20,207
Licking-Kentucky and Green River subregions (codes 0510, 0511)	8,103	810	206	46,063
Wabash-Patoka-White River subregion (code 0512)	18,537	4,167	848	31,114
Upper and Lower Cumberland River subregion (code 0513)	8,915	3,593	950	43,639
Lower Ohio-Salt River subregion (code 0514)	6,054	2,265	513	24,940
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	17,548	9,288	2,740	80,215
Lower Tennessee including Duck River subregion (code 0604)	2,402	742	100	18,988
Total	110,896	59,508	11,329	434,528

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

- **Reservoir pesticides**. The model partitions the system into a well-mixed surface water layer underlain by a well-mixed sediment layer for simulating the fate of pesticides. The pesticide is partitioned into dissolved and particulate phases in both the water and sediment layers. The major processes simulated by the model are loading, outflow, transformation, volatilization, settling, diffusion, resuspension, and burial.

Calibration

Delivery of surface water and subsurface water from upland processes (HRUs and CEAP sample points) was spatially calibrated for each subregion to ensure that streamflow was in agreement with long-term average runoff for the region. Hydrologic parameters in APEX (cultivated cropland) and SWAT (other HRUs) were adjusted separately for each 8-digit watershed until differences in the long-term water yield were minimized. Time series of predicted annual and monthly streamflow were compared against the monitored counterpart. If necessary, the channel losses, seepage, and evaporation losses in reservoirs were adjusted to match the predicted flow time series with that of observed data. The calibration period is from 1961–1990 and the validation period from 1991–2006. Most of the flow calibration was carried out for the upland runoff with minimal or no parameterization for the time series of annual and monthly streamflow. [27]

For sediment calibration, observations were taken from USGS monitoring stations. Most of the sediment observations were grab sample concentrations of suspended sediment. These, along with monitored daily flow data were processed using a load estimator or load runner program to estimate annual average sediment load. The estimated annual average sediment load was used to validate the predicted sediment load from HUMUS. In the Ohio-Tennessee River Basin, predicted sediment load was calibrated/validated to match the observations collected at eight different gauging stations. For calibration of upland soil erosion, soil erodibility factor and residue cover were adjusted.

For adjusting instream sediment load, parameters controlling stream power and sediment carrying capacity of the channel were adjusted. Delivery ratios from field to 8-digit watershed and 8-digit watershed to river were adjusted to match predicted sediment load with that of observations for each validation station. Where necessary, parameters affecting settling of sediment in reservoirs were also adjusted.

Eight gauging stations (the same as for sediment calibration) were selected in the Ohio-Tennessee River Basin for nutrient calibration. Most of the data for nutrient calibration were taken from the USGS-NASQAN data monitoring program. Nutrient observations were available for five gauging stations for the Ohio-Tennessee River Basin including two in Ohio and three in its tributaries (one being the Tennessee River). For the remaining three stations in the Tennessee River Basin, grab samples from the USGS regular monitoring stations were used. Nutrient loads were estimated from grab sample concentrations using the same procedure outlined for sediment.

For calibration of upland nutrient load, parameters controlling nutrient uptake by plants, leaching to groundwater and mineralization were adjusted. For calibration of instream nutrient load, parameters affecting benthic source rate, mineralization, hydrolysis and settling with sediment were adjusted. Where necessary, parameters affecting settling of nutrients in reservoirs were also adjusted.

Data available for atrazine calibration are limited. The calibration data was from USGS monitoring stations. Only the soluble form of atrazine is calibrated because atrazine is most likely to appear in soluble form rather than with sediment. Two gauging stations were selected to calibrate soluble atrazine; one close to the outlet of the Tennessee River and the other near the outlet of the Ohio River. The delivery ratio and instream parameters controlling decay, settling, burial and resuspension of atrazine were adjusted to match predicted atrazine load with that of observations.

The “background” scenario

An additional scenario was conducted to represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by simulating with APEX a grass-and-tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.[28] All SWAT modeling remained the same for this scenario. Thus, “background” loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Source Loads and Instream Loads

All source loads are introduced into SWAT at the outlet of each watershed (8-digit hydrologic unit code [HUC]). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present.[29]

[27] For a complete documentation of calibration procedures and results for the Ohio-Tennessee River Basin, see “Calibration and Validation of CEAP HUMUS” at http://www.nrcs.usda.gov/technical/nri/ceap.

[28] In a natural ecosystem, the vegetative cover would include a mix of species, which would continually change until a stable ecosystem was established. APEX allows for multiple species and simulates plant competition over time according to plant growth, canopy cover, vegetative form, and relative maturity or growth stage. The initial mix of species at the beginning of the 47-year simulation was similar to the mix of grasses and trees used to establish long-term conserving cover. Mixes included at least one grass and one legume. Over the 47-year simulation, the mix of grasses and trees shifted due to plant competition. The grass species typically dominate in the simulation until shaded out by tree cover. For further details on how the background simulation was conducted, see “Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment” at http://www.nrcs.usda.gov/technical/nri/ceapl.

[29] For a complete documentation of HUMUS/SWAT as it was used in this study, see “The HUMUS/SWAT National Water Quality Modeling System and Databases” at http://www.nrcs.usda.gov/technical/nri/ceap.

A sediment delivery ratio was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The sediment delivery ratio used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU.[30]

In addition to the sediment delivery ratio, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentrations transported with sediment to the watershed outlet divided by their concentrations at the edge of the field. As sediment is transported from the edge of field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

There are four points in the modeling process at which source loads or instream loads are assessed, shown in the schematic in figure 79 for sediment.

1. Edge-of-field loads from cultivated cropland—aggregated APEX model output as reported in the previous chapter.

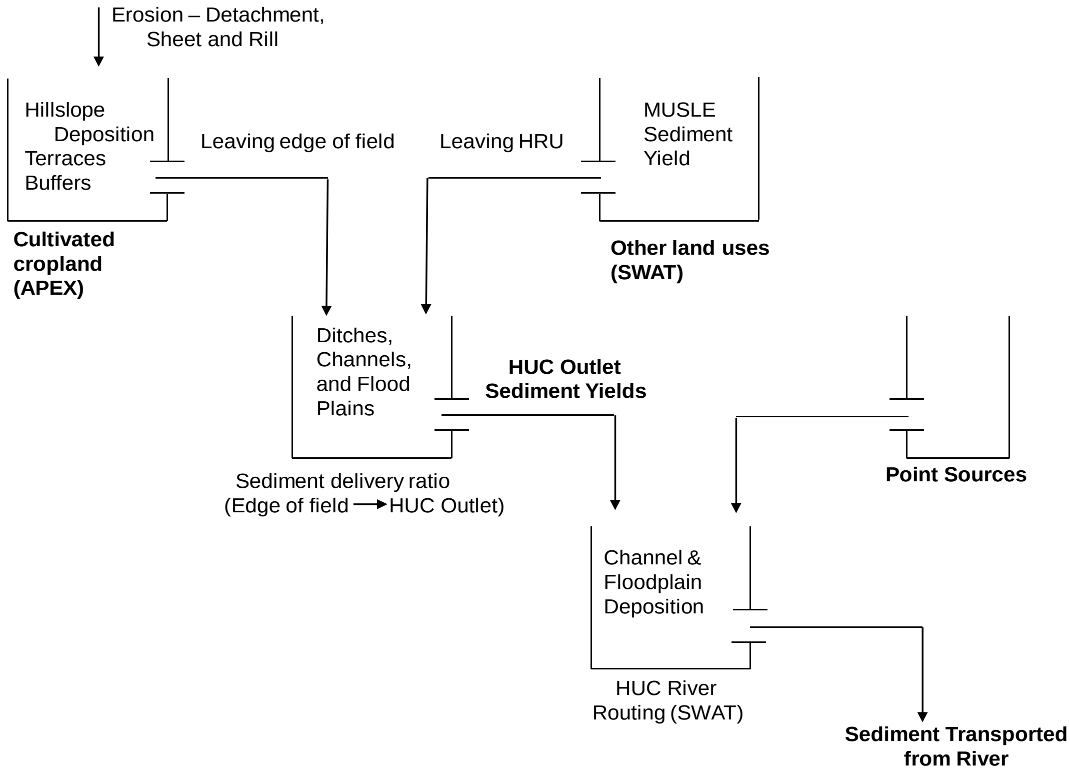
2. Delivery to the watershed outlet from cultivated cropland—aggregated edge-of-field loads after application of delivery ratios. Loadings delivered to streams and rivers differ from the amount leaving the field because of losses during transport from the field to the stream. Delivery ratios are used to make this adjustment.

3. Delivery to the watershed outlet from land uses other than cultivated cropland as simulated by SWAT, after application of delivery ratios. Point sources are included.

4. Loadings in the stream or river at a given point. Instream loads include loadings delivered to the watershed outlet from all sources as well as loads delivered from upstream watersheds, after accounting for channel and reservoir processes.

[30] For a complete documentation of delivery ratios used for the Ohio-Tennessee River Basin, see "Delivery Ratios Used in CEAP Cropland Modeling" at http://www.nrcs.usda.gov/technical/nri/ceap.

Figure 79. Schematic of sediment sources and delivery as modeled with HUMUS/SWAT for the Ohio-Tennessee River Basin



"Legacy Phosphorus" Not Accounted for in Modeling

"Legacy phosphorus" results from the over-application of phosphorus on farm fields in past years. When excessive amounts of fertilizer or manure are applied to a farm field, soil phosphorus levels increase dramatically. It may take many years or even decades for phosphorus levels to return to background levels once these practices are halted. Use of soil testing to determine the need for phosphorus applications can prevent further over-application, but there remains other phosphorus material locked into the soil profile within the field, along the edge of the field and drainageways, and in streambeds that cannot be offset by current management activities.

In addition, the transport of sediment—and the phosphorus bound to those particles—from farm fields to rivers and streams can take many years. Eroded soil particles leaving a farm field can be deposited where runoff slows or ponding occurs before reaching a stream or river. Once the sediment has entered streams, some of the soil particles settle out and can remain in the streambed or settle on the floodplain when the water is high and slow moving. These sediments can remain in place for years until a storm creates enough surface water runoff to re-suspend the previously eroded soil, or until streamflow cuts into streambanks made up of deposits of previously eroded soil. Windborne sediment transported into waterways can similarly be a mixture of newly eroded and previously eroded materials.

Consequently, the phosphorus content of eroded soil from farm fields can be high even when excessive amounts of fertilizer or manure are no longer being applied, including eroded soil from land that is not currently farmed. The measured phosphorus levels in rivers and streams include not only phosphorus lost from farm fields as a result of current farming activities but also "legacy phosphorus" adsorbed to soil particles as a result of prior farming activities. Some of this sediment-adsorbed "legacy phosphorus" can be solubilized by chemical reactions within the water body and measured as soluble phosphorus.

The simulation models used in this study do not account for these "legacy phosphorus" levels. There is recognition, however, that "legacy phosphorus" can be an important contributor to current levels of instream phosphorus loads, including soluble phosphorus loads.

Modeling Land Use in the Ohio-Tennessee River Basin

The USGS National Land-Cover Database for 2001 (Homer et al. 2007) was the principal source of acreage estimates for HUMUS/SWAT modeling. The 2003 National Resources Inventory (USDA-NRCS 2007) was used to adjust NLCD cropland acreage estimates to include acres in Conservation Reserve Program General Signups, used here to represent cropland in long-term conserving cover. Consequently, cultivated cropland acres used to simulate the water quality effects of conservation practices differ slightly from the cropped acres reported in the previous chapters, which were estimated on the basis of the CEAP Cropland sample.

Estimates of the acreage by land use, exclusive of water, used in the model simulation to estimate the effects of conservation practices in this chapter are presented in figure 80 and table 39. Half of the cultivated cropland acres (13.5 million acres) are in the Wabash-Patoka-White River subregion (code 0512). Three subregions each have 7 to 8 percent of the cultivated cropland in the region—the Scioto River subregion (code 0506), the Great Miami subregion (code 0508), and the Lower Ohio-Salt River subregion (code 0514). The other subregions each have less than 5 percent of the cultivated cropland in the region.

Figure 80. Percent acres for land use/cover types in the Ohio-Tennessee River Basin, exclusive of water

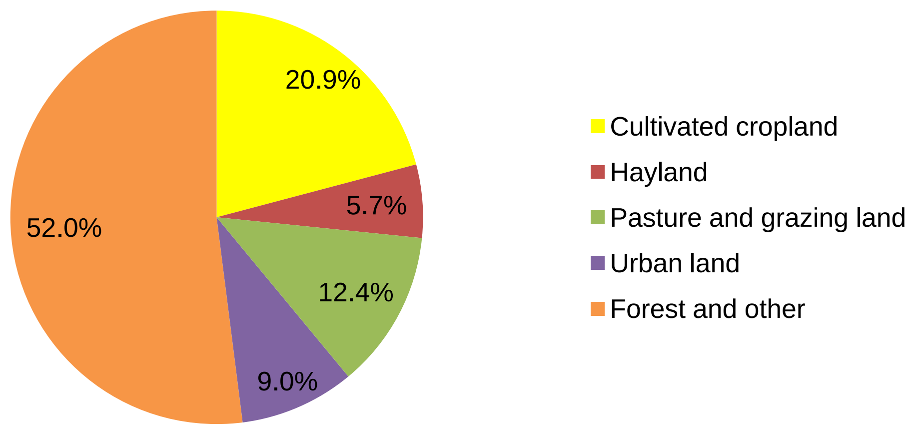


Table 39. Acres by land use, exclusive of water, used in model simulations to estimate instream sediment, nutrient, and atrazine loads for the Ohio-Tennessee River Basin

Subregions	Cultivated cropland (acres)*	Hay land not in rotation with crops (acres)	Pasture and grazing land not in rotation with crops (acres)**	Urban land (acres)	Forest and other (acres)***	Total land exclusive of water (acres)
Ohio River Basin						
Allegheny and Monongahela River subregions (codes 0501, 0502)	695,757	724,196	937,050	1,032,935	8,681,398	12,071,336
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	726,617	539,210	612,989	1,027,059	5,529,763	8,435,638
Muskingum River subregion (code 0504)	1,258,752	374,997	517,705	608,528	2,320,899	5,080,882
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)****	2,233,008	441,647	1,521,488	1,279,585	10,249,329	15,725,058
Great Miami subregion (code 0508)	1,983,455	97,838	260,416	516,252	546,893	3,404,854
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	891,349	283,718	758,082	657,510	3,010,869	5,601,528
Licking-Kentucky and Green River subregions (codes 0510, 0511)	1,129,703	1,414,861	2,683,004	854,831	6,542,147	12,624,546
Wabash-Patoka-White River subregion (code 0512)	13,516,353	354,904	1,046,727	1,934,830	4,028,220	20,881,033
Upper and Lower Cumberland River subregion (code 0513)	998,487	909,409	1,652,440	933,502	6,750,258	11,244,096
Lower Ohio-Salt River subregion (code 0514)	1,978,999	583,803	1,116,411	648,042	3,568,901	7,896,156
Tennessee River Basin						
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	793,214	1,309,040	4,015,969	1,811,771	12,561,635	20,491,629
Lower Tennessee including Duck River subregion (code 0604)	619,532	321,299	785,581	258,520	3,025,310	5,010,242
Regional total	26,825,225	7,354,922	15,907,864	11,563,365	66,815,621	128,466,998

*Acres of cultivated cropland include land in long-term conserving cover as well as hay land and pastureland in rotation with crops.
**Includes grass and brush rangeland categories.
***Includes forests (all types), wetlands, horticulture, and barren land.
****The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.
Note: Estimates were obtained from HUMUS databases on land use, and thus cultivated cropland estimates do not exactly match the acreage estimates obtained from the NRI-CEAP sample.

Conservation Practice Effects on Water Quality

HUMUS/SWAT accounts for the transport of water, sediment, pesticides, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans. Not all of the sediment, nutrients, and pesticides that leave farm fields is delivered to streams and rivers. Some material is bound up in various parts of the landscape during transport. In addition, instream degradation processes and streambed deposition and accumulation remove or trap a portion of the sediment, nutrients, and pesticides after delivery to streams and rivers.

The results from the onsite APEX model simulations for cultivated cropland, including land in long-term conserving cover, were integrated into HUMUS/SWAT to assess the effects of conservation practices on instream loads of sediment, nitrogen, phosphorus, and atrazine. The effects of conservation practices on water quality were assessed by comparing HUMUS/SWAT model simulation results for the baseline conservation condition to simulation results for the no-practice scenario.

For the no-practice scenario, only the conditions for cultivated cropland were changed, as described previously. All other aspects of the simulations—including sediment and nutrient loads from point sources and land uses other than cultivated cropland—remained the same.

In summary, findings for the Ohio-Tennessee River Basin indicate that for the baseline conservation condition—

- *Amounts of sediment, nutrients, and atrazine loads* ***delivered to rivers and streams from cultivated cropland sources*** *per year, on average, are:*
    - *14.8 million tons of sediment (53 percent of loads from all sources);*
    - *500 million pounds of nitrogen (49 percent of loads from all sources);*
    - *55 million pounds of phosphorus (48 percent of loads from all sources); and*
    - *244,000 pounds of atrazine.*

- *Instream* ***loads from all sources delivered from the region to the Mississippi River*** *per year, on average, are:*
    - *26.3 million tons of sediment (20 percent attributable to cultivated cropland sources);*
    - *897 million pounds of nitrogen (49 percent attributable to cultivated cropland sources);*
    - *88 million pounds of phosphorus (51 percent attributable to cultivated cropland sources); and*
    - *178,000 pounds of atrazine;*

Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have—

- *Reduced sediment, nutrient, and atrazine loads* ***delivered to rivers and streams from cultivated cropland sources*** *per year, on average, by:*
    - *55 percent for sediment;*
    - *26 percent for nitrogen;*
    - *32 percent for phosphorus, and*
    - *18 percent for atrazine.*

- *Reduced instream* ***loads from all sources delivered from the region to the Mississippi River*** *per year, on average, by:*
    - *16 percent for sediment;*
    - *15 percent for nitrogen;*
    - *21 percent for phosphorus, and*
    - *18 percent for atrazine.*

Sediment

Baseline condition. Model simulation results show that of the 41.6 million tons of sediment exported from farm fields in the Ohio-Tennessee River Basin (table 40), about 14.8 million tons are delivered to rivers and streams each year (table 41), on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 0.6 ton per acre of cultivated cropland is delivered to rivers and streams per year, on average for the region (table 41).

About half of the sediment delivered to rivers and streams originates in the two subreigons with the most cultivated cropland acres—the Wabash-Patoka-White River subregion (code 0512) with 33 percent of the total and the Lower Ohio-Salt River subregions (code 0514) (table 41) with 17 percent of the total.

On a per-acre basis, sediment delivery is highest in the Allegheny and Monongahela River subregions (codes 0501, 0502), averaging 4.3 tons per cultivated cropland acre lost at the edge of the field and 1.5 tons per acre delivered to rivers and streams (tables 40 and 41). Per acre sediment delivery is also high in the Lower Ohio-Salt River subregion (code 0514), averaging 3.5 tons per cultivated cropland acre lost at the edge of the field and 1.3 tons per acre delivered to rivers and streams (tables 39 and 40). Other subregions have sediment loads delivered to rivers and streams of 1 ton per acre or less.

Sediment delivered to rivers and streams from cultivated cropland represents about 53 percent of the total sediment load delivered from all sources in the region (table 42, fig. 81). This percentage ranges, however, from a low of 11 percent in Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603) to a high of 88 percent in the Wabash-Patoka-White River subregion (code 0512).

Instream sediment loads delivered from all sources in the region to the Mississippi River, after accounting for instream deposition and transport processes, total about 26.3 million tons per year, averaged over the 47 years of weather as simulated in the model (table 43). Of this, about 20 percent is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 43).

Tributary subregions with the highest percentage of instream loads attributable to cultivated cropland are—

- The Wabash-Patoka-White River (code 0512) with 62 percent,
- The Great Miami River (code 0508) with 58 percent, and
- The Green River (code 0511) with 48 percent.

Instream sediment loads delivered from the Tennessee River to the Ohio River are small relative to instream sediment loads in the mainstem of the Ohio River, totaling only 617,000 tons at the outlet. Sediment originating from cultivated cropland in the Tennessee River Basin is about 9 percent of the total edge-of-field load for the region (table 40), but represents less than 3 percent of the instream loads at the confluence of the Tennessee and Ohio Rivers (table 43). The various dams and reservoirs in the Tennessee River Basin diminish the sediment loads exported from the basin.

Effects of conservation practices. Sediment loads delivered to streams and rivers would have been much larger if soil erosion control practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of sediment from fields to rivers and streams by about 55 percent (table 41), on average. Reductions due to conservation practices are similar throughout the region, ranging from a low of 51 percent for the Muskingum River subregion (code 0504) to a high of 65 percent for the Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, and 0507).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of sediment from the Ohio-Tennessee River Basin to the Mississippi River by about 16 percent overall (table 43). Without conservation practices, the total sediment delivered to the Mississippi River would be larger by 5.1 million tons (table 43 and fig. 82) per year. The largest percent reduction in instream loads among tributary subregions is in the Great Miami subregion (code 0508)—41 percent, followed by the Wabash-Patoka-White River subregion (code 0512) at 36 percent and the Green River (code 0511) at 35 percent.

Table 40. Average annual sediment loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Amount (1,000 tons)	Percent of basin total	Tons delivered per cultivated cropland acre	No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Percent
Allegheny and Monongahela River subregions (codes 0501, 0502)	3,009	7	4.3	6,180	3,171	51
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	1,060	3	1.5	2,180	1,120	51
Muskingum River subregion (code 0504)	2,410	6	1.9	4,690	2,280	49
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	1,296	3	0.6	3,620	2,323	64
Great Miami subregion (code 0508)	1,970	5	1.0	4,510	2,540	56
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	1,110	3	1.2	2,280	1,170	51
Licking-Kentucky and Green River subregions (codes 0510, 0511)	3,418	8	3.0	7,802	4,384	56
Wabash-Patoka-White River subregion (code 0512)	13,600	33	1.0	30,100	16,500	55
Upper and Lower Cumberland River subregion (code 0513)	2,940	7	2.9	7,550	4,610	61
Lower Ohio-Salt River subregion (code 0514)	6,980	17	3.5	14,400	7,420	52
subtotal	37,793	91	1.5	83,312	45,518	55
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	1,950	5	2.5	4,273	2,323	54
Lower Tennessee including Duck River subregion (code 0604)	1,830	4	3.0	3,950	2,120	54
subtotal	3,780	9	2.7	8,223	4,443	54
Regional total	41,573	100	1.5	91,535	49,961	55

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 41. Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Amount (1,000 tons)	Percent of basin total	Tons delivered per cultivated cropland acre	No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Percent
Allegheny and Monongahela River subregions (codes 0501, 0502)	1,039	7	1.5	2,160	1,121	52
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	361	2	0.5	762	401	53
Muskingum River subregion (code 0504)	832	6	0.7	1,710	878	51
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	476	3	0.2	1,348	872	65
Great Miami subregion (code 0508)	680	5	0.3	1,600	920	58
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	396	3	0.4	845	449	53
Licking-Kentucky and Green River subregions (codes 0510, 0511)	1,162	8	1.0	2,670	1,508	57
Wabash-Patoka-White River subregion (code 0512)	4,921	33	0.4	10,900	5,979	55
Upper and Lower Cumberland River subregion (code 0513)	1,031	7	1.0	2,640	1,609	61
Lower Ohio-Salt River subregion (code 0514)	2,535	17	1.3	5,240	2,705	52
subtotal	13,433	91	0.5	29,875	16,442	55
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	694	5	0.9	1,519	826	54
Lower Tennessee including Duck River subregion (code 0604)	636	4	1.0	1,400	764	55
subtotal	1,329	9	0.9	2,919	1,590	54
Regional total	14,762	100	0.6	32,794	18,032	55

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 40 are due to the application of delivery ratios, which were used to simulate delivery of sediment from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 42. Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs) in the Ohio-Tennessee River Basin, baseline conservation condition, by source

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and grazing land	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 tons)			
Allegheny and Monongahela River subregions (codes 0501, 0502)	2,161	1,039	133	61	419	36	472
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	993	361	49	31	363	52	136
Muskingum River subregion (code 0504)	1,195	832	76	26	197	5	58
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	1,674	476	59	112	483	11	533
Great Miami subregion (code 0508)	879	680	16	11	154	9	9
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	790	396	26	45	235	8	81
Licking-Kentucky and Green River subregions (codes 0510, 0511)	2,090	1,162	124	164	323	2	314
Wabash-Patoka-White River subregion (code 0512)	5,611	4,921	36	47	510	6	92
Upper and Lower Cumberland River subregion (code 0513)	2,080	1,031	73	141	392	5	438
Lower Ohio-Salt River subregion (code 0514)	2,979	2,535	45	61	231	5	101
subtotal	20,452	13,433	638	700	3,307	140	2,234
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	6,179	694	233	724	2,787	24	1,718
Lower Tennessee including Duck River subregion (code 0604)	1,381	636	37	119	376	2	212
subtotal	7,560	1,329	269	843	3,164	26	1,929
Regional total	28,012	14,762	907	1,543	6,471	166	4,164
				Percent of all sources			
Allegheny and Monongahela River subregions (codes 0501, 0502)	100	48	6	3	19	2	22
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	100		5	3	37	5	14
Muskingum River subregion (code 0504)	100	70	6	2	16	0	5
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	100	28	4	7	29	1	32
Great Miami subregion (code 0508)	100 36	77	2	1	18	1	1
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	100	50	3	6	30	1	10
Licking-Kentucky and Green River subregions (codes 0510, 0511)	100	56	6	8	15	0	15
Wabash-Patoka-White River subregion (code 0512)	100	88	1	1	9	0	2
Upper and Lower Cumberland River subregion (code 0513)	100	50	4	7	19	0	21
Lower Ohio-Salt River subregion (code 0514)	100	85	2	2	8	0	3
subtotal		66	3	3	16	1	11
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	100	11	4	12	45	0	28
Lower Tennessee including Duck River subregion (code 0604)	100	46	3	9	27	0	15
subtotal 100		18	4	11	42	0	26
Regional total	100		3	6	23	1	15

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land. 100

Figure 81. Percentage by source of average annual sediment loads delivered to rivers and streams in the Ohio-Tennessee River Basin, baseline conservation condition

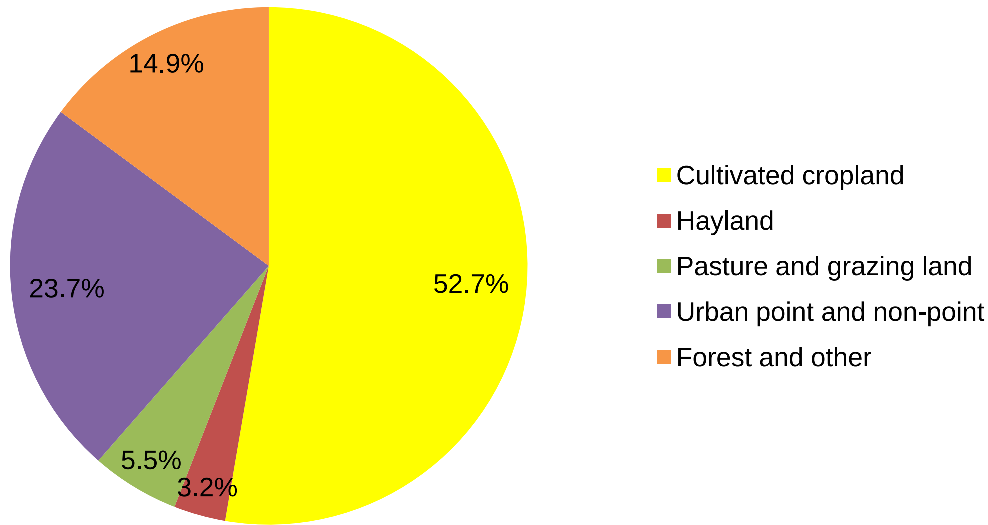
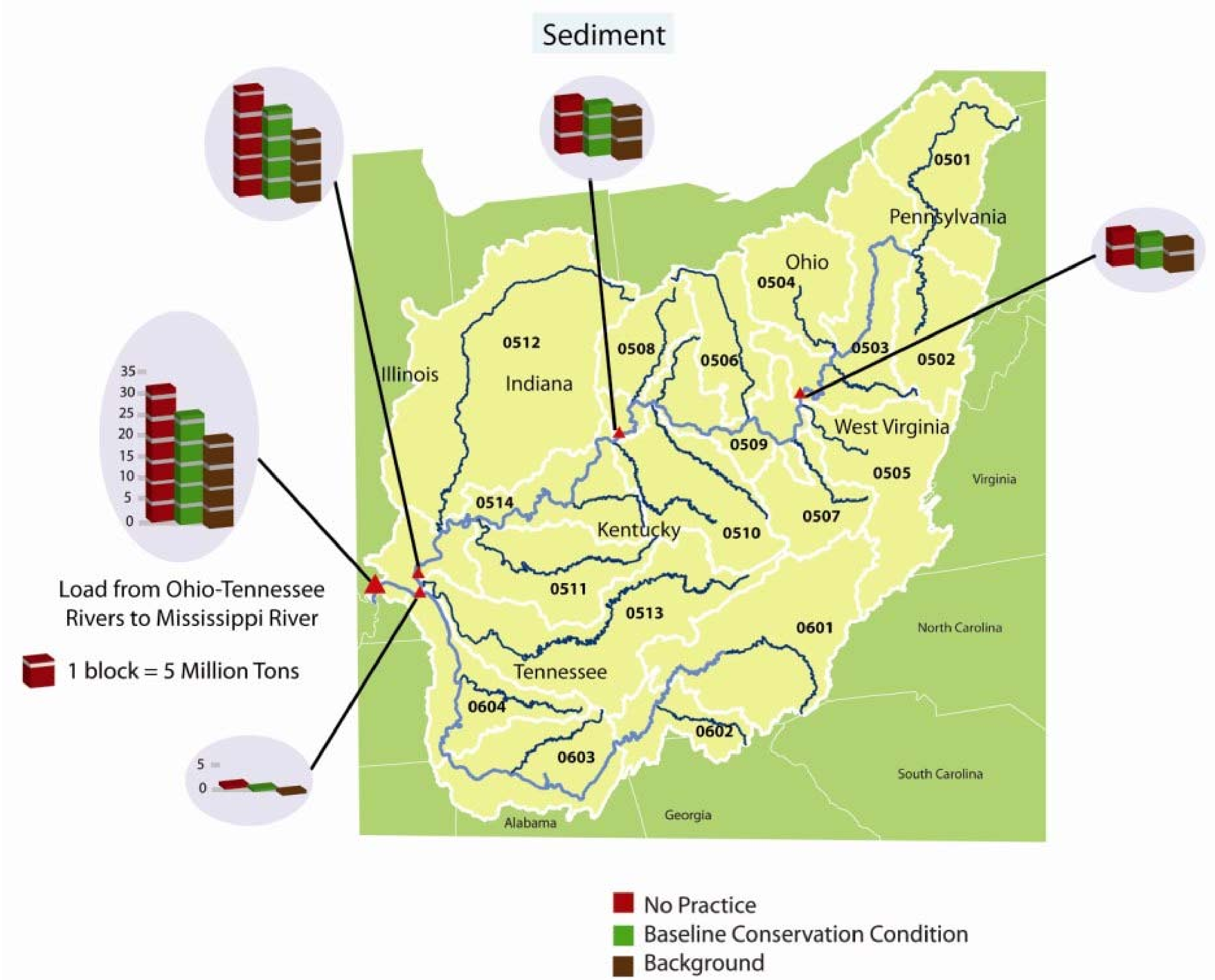


Table 43. Average annual ***instream sediment loads*** (all sources) for the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Load from all sources (1,000 tons)	Baseline conservation condition: Background sources** (1,000 tons)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Reductions in loads due to conservation practices: Percent
Ohio River Basin--tributary subregions						
Allegheny River (code 0501)	1,860	1,550	17	2,190	330	15
Monongahela River (code 0502)	353	287	19	462	109	24
Muskingum River (code 0504)	1,610	1,220	24	1,960	350	18
Kanawha River (code 0505)	4,090	4,080	<1	4,130	40	1
Scioto River (code 0506)	765	593	22	1,020	255	25
Guyandotte-Big Sandy River (code 0507)	1,230	1,230	0	1,230	0	0
Great Miami River (code 0508)	513	214	58	875	362	41
Licking-Kentucky River (code 0510)	464	445	4	513	49	10
Green River (code 0511)	911	473	48	1,400	489	35
Wabash-Patoka-White River (code 0512)	3,150	1,190	62	4,940	1,790	36
Upper and Lower Cumberland River (code 0513)	1,620	1,300	20	2,130	510	24
Ohio River--Outlets along mainstem						
Upper Ohio-Beaver-Little Kanawha (code 0503)	8,580	8,070	6	9,050	470	5
Middle Ohio-Raccoon-Little-Miami (code 0509)	12,700	11,800	7	13,700	1,000	7
Ohio River before the confluence of Tennessee River	21,400	16,800	21	25,600	4,200	16
Tennessee River--Outlets along mainstem						
Upper Tennessee including French Broad-Holston (code 0601)	260	260	0	260	0	0
Middle Tennessee including Hiwassee River (code 0602)	456	447	2	468	12	3
Middle Tennessee including Elk River (code 0603)	581	493	15	696	115	17
Lower Tennessee-Duck River (code 0604)	617	470	24	776	159	20
Ohio River after the confluence of Tennessee River (code 0514)	26,300	21,000	20	31,400	5,100	16

** “Background sources” represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Figure 82. Estimates of average annual instream sediment loads for the baseline conservation condition compared to the no-practice scenario for the Ohio-Tennessee River Basin*



* Instream sediment loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 43.

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Total Nitrogen

Baseline condition. Model simulation results show that about 765 million pounds of nitrogen are lost from farm fields (edge-of-field) per year within the Ohio-Tennessee River Basin (table 44) under conditions represented by the baseline conservation condition, which includes farming activities and conservation practices in use during the period 2003 to 2006. Of this, about 500 million pounds are delivered into rivers and streams per year, on average (table 45).

About half of the nitrogen delivered to rivers and streams originates in the Wabash-Patoka-White River subregion (code 0512), which also has about half of the cultivated cropland acres in the region. Generally, the amount of nitrogen delivered to rivers and streams varies among subregions according to the number of cultivated cropland acres in each subregion.

On a per-acre basis, nitrogen delivery to rivers and streams averages about 19 pounds per acre per year from cultivated cropland for the region (table 45). Per-acre nitrogen delivery is highest in the Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603), averaging 31 pounds per acre per year (table 45). Per-acre nitrogen delivery is lowest in the Middle Ohio-Raccoon-Little-Miami River subregion (code 0509) and the Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, and0507), averaging 16 pounds per acre per year.

Nitrogen delivered to rivers and streams from cultivated cropland represents about 49 percent of the total nitrogen load delivered from all sources in the region (table 46, fig. 83). This percentage ranges, however, from a low of 20 percent in the Allegheny and Monongahela River subregions (codes 0501, 0502) and the Upper Ohio-Beaver-Little Kanawha River subregion (code 0503) to a high of 81 percent in the Wabash-Patoka-White River subregion (code 0512).

Instream nitrogen loads delivered from all sources in the region to the Mississippi River, after accounting for instream deposition and transport processes, totals about 897 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 47). Of this, about 49 percent is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 47.

Tributary subregions with the highest percentage of instream loads attributable to cultivated cropland are—

- The Wabash-Patoka-White River (code 0512) with 80 percent,
- The Scioto River (code 0506) with 72 percent, and
- The Great Miami River (code 0508) with 61 percent.

Effects of conservation practices. Nitrogen loads delivered to streams and rivers would have been larger if conservation practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of nitrogen from fields to rivers and streams by about 26 percent (table 45), on average. Within the subregions, reductions due to conservation practices range from a low of 18 percent for the Middle Ohio-Raccoon-Little-Miami River subregion (code 0509) to a high of 40 percent for the Allegheny and Monongahela River subregions (codes 0501, 0502).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of nitrogen from the Ohio-Tennessee River Basin to the Mississippi River by about 15 percent overall (table 47). Without conservation practices, the total nitrogen delivered to the Mississippi River would be larger by 158 million pounds (table 47 and fig. 84) per year. The largest percent reduction in instream loads among tributary subregions is in the Muskingum River subregion (code 0504)—20 percent, followed by the Wabash-Patoka-White River subregion (code 0512) at 19 percent.

Table 44. Average annual nitrogen loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Percent
Allegheny and Monongahela River subregions (codes 0501, 0502)	29,960	4	43	48,600	18,640	38
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	22,000	3	30	32,700	10,700	33
Muskingum River subregion (code 0504)	34,400	4	27	52,400	18,000	34
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	50,051	7	22	67,124	17,073	25
Great Miami subregion (code 0508)	54,400	7	27	69,900	15,500	22
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	22,800	3	26	27,800	5,000	18
Licking-Kentucky and Green River subregions (codes 0510, 0511)	39,710	5	35	58,340	18,630	32
Wabash-Patoka-White River subregion (code 0512)	348,000	46	26	456,000	108,000	24
Upper and Lower Cumberland River subregion (code 0513)	44,300	6	44	67,300	23,000	34
Lower Ohio-Salt River subregion (code 0514)	71,500	9	36	97,900	26,400	27
subtotal	717,121	94	28	978,064	260,943	27
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	30,510	4	38	40,300	9,790	24
Lower Tennessee including Duck River subregion (code 0604)	17,100	2	28	25,700	8,600	33
subtotal	47,610	6	34	66,000	18,390	28
Regional total	764,731	100	29	1,044,064	279,333	27

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 45. Average annual nitrogen loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Percent
Allegheny and Monongahela River subregions (codes 0501, 0502)	17,463	3	25	28,990	11,527	40
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	14,115	3	19	21,400	7,285	34
Muskingum River subregion (code 0504)	21,503	4	17	33,400	11,897	36
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	34,682	7	16	46,164	11,482	25
Great Miami subregion (code 0508)	36,040	7	18	46,200	10,160	22
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	14,471	3	16	17,600	3,129	18
Licking-Kentucky and Green River subregions (codes 0510, 0511)	23,612	5	21	34,990	11,378	33
Wabash-Patoka-White River subregion (code 0512)	233,220	47	17	303,000	69,780	23
Upper and Lower Cumberland River subregion (code 0513)	26,358	5	26	40,200	13,842	34
Lower Ohio-Salt River subregion (code 0514)	41,066	8	21	56,200	15,134	27
subtotal	462,530	92	18	628,144	165,614	26
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	24,645	5	31	31,850	7,205	23
Lower Tennessee including Duck River subregion (code 0604)	13,457	3	22	19,900	6,443	32
subtotal	38,102	8	27	51,750	13,648	26
Regional total	500,632	100	19	679,894	179,262	26

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 44 are due to the application of delivery ratios, which were used to simulate delivery of nitrogen from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 46. Average annual nitrogen loads ***delivered to watershed outlets*** (8-digit HUCs***)*** in the Ohio-Tennessee River Basin, baseline conservation condition, by source

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and grazing land	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Allegheny and Monongahela River subregions (codes 0501, 0502)	88,576	17,463	5,797	7,284	12,554	23,964	21,515
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	70,836	14,115	3,257	4,380	13,372	27,231	8,481
Muskingum River subregion (code 0504)	48,800	21,503	3,533	5,998	8,015	7,013	2,738
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	90,524	34,682	2,421	7,733	17,774	9,768	18,146
Great Miami subregion (code 0508)	53,987	36,040	1,104	2,397	8,687	5,097	661
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	36,330	14,471	1,612	3,724	8,325	4,213	3,985
Licking-Kentucky and Green River subregions (codes 0510, 0511)	74,882	23,612	7,007	22,535	11,141	1,620	8,967
Wabash-Patoka-White River subregion (code 0512)	287,996	233,220	2,831	10,452	28,656	8,334	4,503
Upper and Lower Cumberland River subregion (code 0513)	77,221	26,358	4,257	15,090	13,265	7,186	11,066
Lower Ohio-Salt River subregion (code 0514)	70,914	41,066	2,989	8,396	9,238	4,530	4,693
subtotal	900,065	462,530	34,808	87,990	131,026	98,956	84,755
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	100,386	24,645	2,822	16,589	13,660	18,576	24,094
Lower Tennessee including Duck River subregion (code 0604)	26,395	13,457	847	3,970	2,565	1,485	4,071
subtotal	126,781	38,102	3,669	20,559	16,225	20,061	28,166
Regional total	1,026,846	500,632	38,477	108,549	147,251	119,017	112,920
				Percent of all sources			
Allegheny and Monongahela River subregions (codes 0501, 0502)	100	20	7	8	14	27	24
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	100	20	5	6	19	38	12
Muskingum River subregion (code 0504)	100	44	7	12	16	14	6
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	100		3	9	20	11	20
Great Miami subregion (code 0508)	100	67	2	4	16	9	1
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	100	40	4	10	23	12	11
Licking-Kentucky and Green River subregions (codes 0510, 0511)	100	32	9	30	15	2	12
Wabash-Patoka-White River subregion (code 0512)	100	81	1	4	10	3	2
Upper and Lower Cumberland River subregion (code 0513)	100	34	6	20	17	9	14
Lower Ohio-Salt River subregion (code 0514)	100	58	4	12	13	6	7
subtotal	100		4	10	15	11	9
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	100	25	3	17	14	19	24
Lower Tennessee including Duck River subregion (code 0604)	100	51	3	15	10	6	15
subtotal	100		3	16	13	16	22
Regional total	100		4	11	14	12	11

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

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Figure 83. Percentage by source of average annual nitrogen loads delivered to rivers and streams in the Ohio-Tennessee River Basin, baseline conservation condition

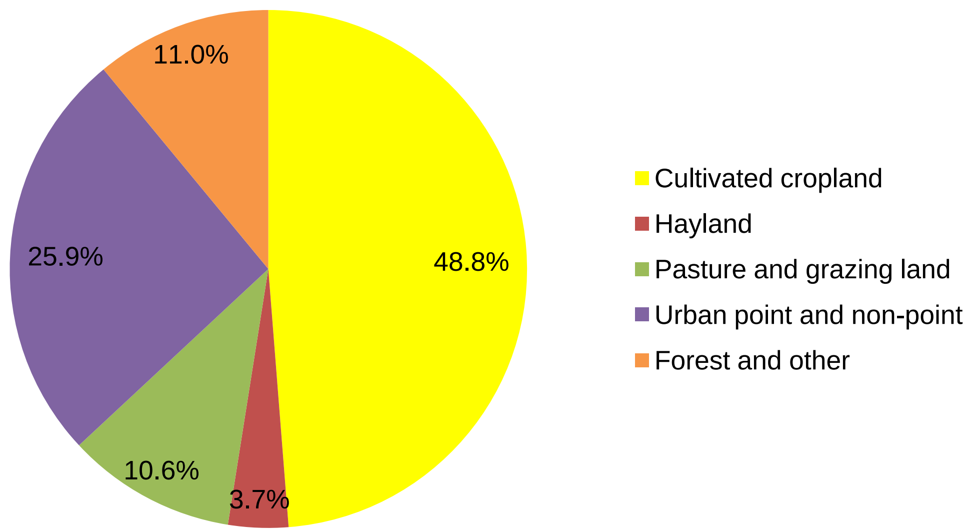
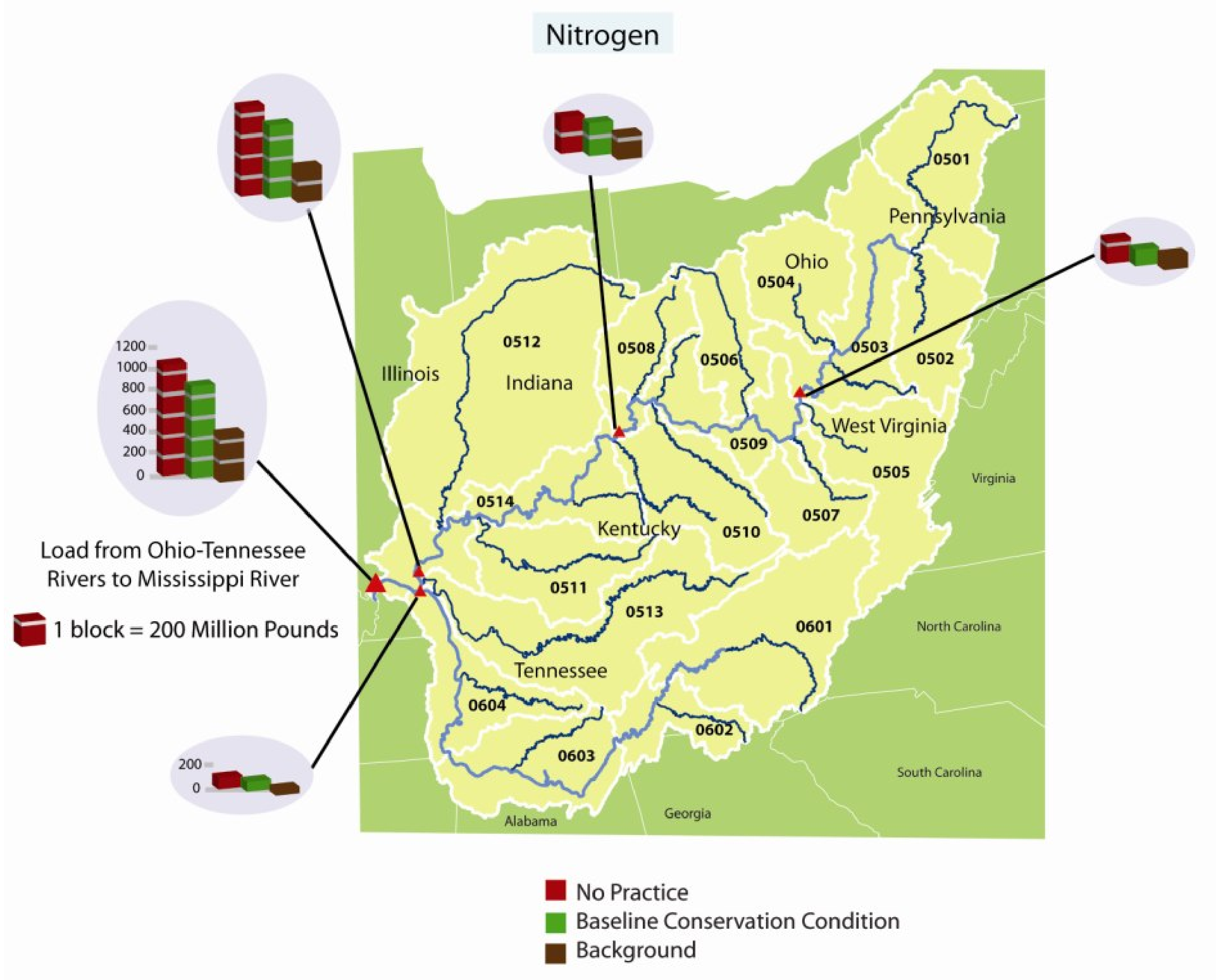


Table 47. Average annual ***instream nitrogen loads*** (all sources) for the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Load from all sources (1,000 pounds)	Baseline conservation condition: Background sources* (1,000 pounds)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Ohio River Basin--tributary subregions						
Allegheny River (code 0501)	63,014	48,918	22	71,553	8,540	12
Monongahela River (code 0502)	24,561	23,002	6	27,760	3,199	12
Muskingum River (code 0504)	46,143	25,729	44	57,466	11,323	20
Kanawha River (code 0505)	31,538	30,556	3	32,793	1,255	4
Scioto River (code 0506)	43,106	12,268	72	52,462	9,356	18
Guyandotte-Big Sandy River (code 0507)	12,429	12,220	2	12,464	35	0
Great Miami River (code 0508)	25,982	10,239	61	30,142	4,160	14
Licking-Kentucky River (code 0510)	18,480	17,408	6	19,202	722	4
Green River (code 0511)	42,555	22,468	47	52,030	9,475	18
Wabash-Patoka-White River (code 0512)	270,556	54,776	80	333,235	62,679	19
Upper and Lower Cumberland River (code 0513)	65,723	41,063	38	78,665	12,942	16
Ohio River--Outlets along mainstem						
Upper Ohio-Beaver-Little Kanawha (code 0503)	195,140	150,586	23	224,414	29,274	13
Middle Ohio-Raccoon-Little-Miami (code 0509)	334,679	230,857	31	380,202	45,522	12
Ohio River before the confluence of Tennessee River	728,810	352,293	52	860,457	131,647	15
Tennessee River						
Upper Tennessee including French Broad-Holston (code 0601)	51,200	48,400	5	52,200	1,000	2
Middle Tennessee including Hiwassee River (code 0602)	65,100	60,600	7	66,500	1,400	2
Middle Tennessee including Elk River (code 0603)	73,500	51,200	30	79,700	6,200	8
Lower Tennessee-Duck River (code 0604)	102,000	66,500	35	115,000	13,000	11
Ohio River after the confluence of Tennessee River (code 0514)	897,082	457,965	49	1,054,916	157,834	15

***** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Figure 84. Estimates of average annual instream nitrogen loads for the baseline conservation condition compared to the no-practice scenario for the Ohio-Tennessee River Basin*



* Instream nitrogen loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 47.

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Total Phosphorus

Baseline condition. Model simulation results show that about 116 million pounds of phosphorus are lost from farm fields (edge-of-field) per year within the Ohio-Tennessee River Basin (table 48) under conditions represented by the baseline conservation condition, which includes farming activities and conservation practices in use during the period 2003 to 2006. Of this, about 55 million pounds are delivered into rivers and streams per year, on average (table 49).

Over half of the phosphorus delivered to rivers and streams originates in the two subreigons with the most cultivated cropland acres—the Wabash-Patoka-White River subregion (code 0512) with 41 percent of the total and the Lower Ohio-Salt River subregions (code 0514) (table 49) with 11 percent of the total.

On a per-acre basis, phosphorus delivery to rivers and streams averages about 2.0 pounds per acre per year from cultivated cropland for the region (table 49). Per-acre phosphorus delivery is highest in the Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603), averaging 5.1 pounds per acre per year (table 49). Per-acre phosphorus delivery is also high in the Upper and Lower Cumberland River subregion (code 0513) at 3.8 pounds per acre per year and the Lower Tennessee including Duck River subregion (code 0604) at 3.3 pounds per acre per year. Per-acre phosphorus delivery is lowest in the Upper Ohio-Beaver-Little Kanawha River subregion (code 0503), averaging 1.4 pounds per acre per year.

Phosphorus delivered to rivers and streams from cultivated cropland represents about 48 percent of the total phosphorus load delivered from all sources in the region (table 50, fig. 85). This percentage ranges, however, from a low of 19 percent in the Upper Ohio-Beaver-Little Kanawha River subregion (code 0503) to a high of 84 percent in the Wabash-Patoka-White River subregion (code 0512).

Instream phosphorus loads delivered from all sources in the Ohio-Tennessee River Basin to the Mississippi River, after accounting for instream deposition and transport processes, total about 88 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 51). Of this, about 51 percent is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 51).

Tributary subregions with the highest percentage of instream loads attributable to cultivated cropland are the Wabash-Patoka-White River (code 0512) with 81 percent and the Scioto River (code 0506) with 71 percent.

Effects of conservation practices. Phosphorus loads delivered to streams and rivers would have been larger if conservation practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of phosphorus from fields to rivers and streams by about 32 percent (table 49), on average. Within the subregions, reductions due to conservation practices range from a low of 4 percent for the Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603) to highs of 43 percent for the Upper Ohio-Beaver-Little Kanawha River subregion (code 0503) and 42 percent for the Muskingum River subregion (code 0504).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of phosphorus to the Mississippi River by about 21 percent overall (table 51). Without conservation practices, the total phosphorus delivered from the Ohio-Tennessee River Basin to the Mississippi River would be larger by 22 million pounds per year (table 51 and fig. 86). The largest percent reduction in instream loads among tributary subregions is in the Wabash-Patoka-White River subregion (code 0512) at 35 percent.

Table 48. Average annual phosphorus loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Percent
Allegheny and Monongahela River subregions (codes 0501, 0502)	5,134	4	7.4	8,050	2,916	36
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	2,560	2	3.5	4,620	2,060	45
Muskingum River subregion (code 0504)	4,440	4	3.5	8,030	3,590	45
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	6,584	6	2.9	9,343	2,759	30
Great Miami subregion (code 0508)	6,540	6	3.3	10,400	3,860	37
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	3,940	3	4.4	5,460	1,520	28
Licking-Kentucky and Green River subregions (codes 0510, 0511)	7,691	7	6.8	10,960	3,269	30
Wabash-Patoka-White River subregion (code 0512)	47,200	41	3.5	80,400	33,200	41
Upper and Lower Cumberland River subregion (code 0513)	8,560	7	8.6	11,700	3,140	27
Lower Ohio-Salt River subregion (code 0514)	13,800	12	7.0	20,100	6,300	31
subtotal	106,449	92	4.2	169,063	62,614	37
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	6,277	5	7.9	7,622	1,345	18
Lower Tennessee including Duck River subregion (code 0604)	3,290	3	5.3	5,080	1,790	35
subtotal	9,567	8	6.8	12,702	3,135	25
Regional total	116,016	100	4.3	181,765	65,749	36

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 49. Average annual phosphorus loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Percent
Allegheny and Monongahela River subregions (codes 0501, 0502)	1,956	4	2.8	2,885	929	32
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	1,023	2	1.4	1,800	777	43
Muskingum River subregion (code 0504)	1,905	3	1.5	3,300	1,395	42
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	3,355	6	1.5	4,404	1,050	24
Great Miami subregion (code 0508)	3,052	6	1.5	4,560	1,508	33
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	1,916	4	2.1	2,510	594	24
Licking-Kentucky and Green River subregions (codes 0510, 0511)	3,330	6	2.9	4,407	1,077	24
Wabash-Patoka-White River subregion (code 0512)	22,348	41	1.7	36,700	14,352	39
Upper and Lower Cumberland River subregion (code 0513)	3,784	7	3.8	4,660	876	19
Lower Ohio-Salt River subregion (code 0514)	5,820	11	2.9	8,090	2,270	28
subtotal	48,489	89	1.9	73,316	24,828	34
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	4,084	7	5.1	4,260	176	4
Lower Tennessee including Duck River subregion (code 0604)	2,068	4	3.3	2,840	772	27
subtotal	6,152	11	4.4	7,100	948	13
Regional total	54,640	100	2.0	80,416	25,776	32

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 48 are due to the application of delivery ratios, which were used to simulate delivery of phosphorus from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 50. Average annual phosphorus loads ***delivered to watershed outlets*** (8-digit HUCs***)*** in the Ohio-Tennessee River Basin, baseline conservation condition, by source

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and grazing land	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Allegheny and Monongahela River subregions (codes 0501, 0502)	7,990	1,956	451	827	591	3,132	1,034
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	5,492		184	454	549	2,915	367
Muskingum River subregion (code 0504)	4,606	1,905	243	499	280	1,539	140
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	8,423 1,023	3,355	200	1,090	766	2,087	925
Great Miami subregion (code 0508)	4,948	3,052	50	194	270	1,343	38
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	4,199	1,916		532	494	927	211
Licking-Kentucky and Green River subregions (codes 0510, 0511)	9,024	3,330	571	3,566	556	412	589
Wabash-Patoka-White River subregion (code 0512)	26,478	22,348	161	1,027	1,000	1,696	245
Upper and Lower Cumberland River subregion (code 0513)	9,902	3,784 118	298	2,473	683	1,901	762
Lower Ohio-Salt River subregion (code 0514)	9,235	5,820	207	1,425	450	1,026	306
subtotal	90,296	48,489	2,484	12,087	5,639	16,979	4,619
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	19,369	4,084	690	4,425	2,332	5,479	2,359
Lower Tennessee including Duck River subregion (code 0604)	3,795	2,068	89	773	357	200	309
subtotal	23,164	6,152	778	5,198	2,689	5,679	2,668
Regional total	113,460	54,640	3,262	17,285	8,328	22,658	7,287
				Percent of all sources			
Allegheny and Monongahela River subregions (codes 0501, 0502)	100	24	6	10	7	39	13
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	100		3	8	10	53	7
Muskingum River subregion (code 0504)	100	41	5	11	6	33	3
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	100		2	13	9	25	11
Great Miami subregion (code 0508)	100 19	62	1	4	5	27	1
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	100	46	3	13	12	22	5
Licking-Kentucky and Green River subregions (codes 0510, 0511)	100	37	6	40	6	5	7
Wabash-Patoka-White River subregion (code 0512)	100 40	84	1	4	4	6	1
Upper and Lower Cumberland River subregion (code 0513)	100	38	3	25	7	19	8
Lower Ohio-Salt River subregion (code 0514)	100	63	2	15	5	11	3
subtotal	100		3	13	6	19	5
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	100	21	4	23	12	28	12
Lower Tennessee including Duck River subregion (code 0604)	100	54	2	20	9	5	8
subtotal	100		3	22	12		12
Regional total	100 54		3	15	7	20	6

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

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Figure 85. Percentage by source of average annual phosphorus loads delivered to rivers and streams in the Ohio-Tennessee River Basin, baseline conservation condition

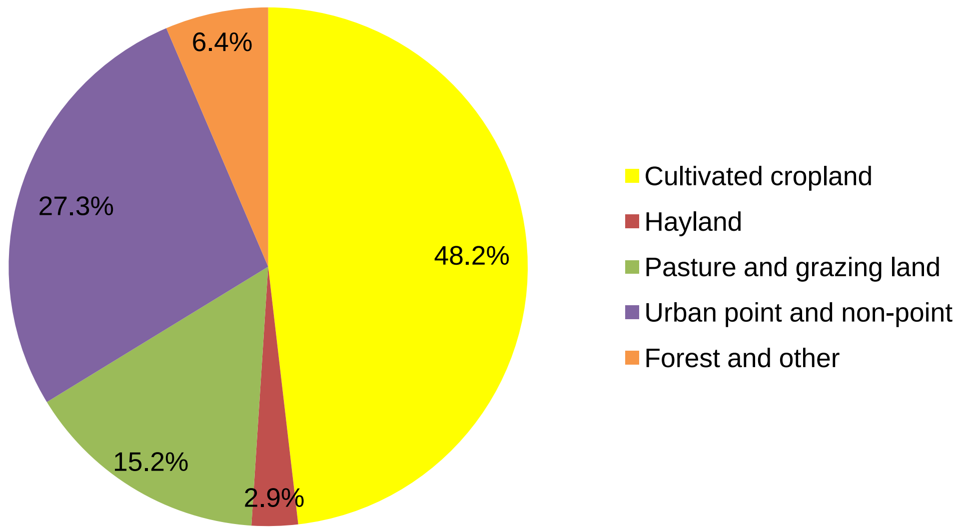

Table 51. Average annual ***instream phosphorus loads*** (all sources) for the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Load from all sources (1,000 pounds)	Baseline conservation condition: Background sources* (1,000 pounds)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Ohio River Basin--tributary subregions						
Allegheny River (code 0501)	4,500	3,360	25	4,940	440	9
Monongahela River (code 0502)	1,780	1,560	12	2,040	260	13
Muskingum River (code 0504)	4,180	2,540	39	5,430	1,250	23
Kanawha River (code 0505)	2,590	2,500	3	2,620	30	1
Scioto River (code 0506)	3,950	1,130	71	4,850	900	19
Guyandotte-Big Sandy River (code 0507)	698	675	3	704	6	1
Great Miami River (code 0508)	4,180	1,750	58	5,360	1,180	22
Licking-Kentucky River (code 0510)	1,930	1,820	6	2,030	100	5
Green River (code 0511)	5,470	2,660	51	6,380	910	14
Wabash-Patoka-White River (code 0512)	24,800	4,670	81	38,400	13,600	35
Upper and Lower Cumberland River (code 0513)	9,180	5,680	38	10,000	820	8
Ohio River--Outlets along mainstem						
Upper Ohio-Beaver-Little Kanawha (code 0503)	13,700	10,300	25	16,100	2,400	15
Middle Ohio-Raccoon-Little-Miami (code 0509)	28,600	18,400	36	33,400	4,800	14
Ohio River before the confluence of Tennessee River	68,100	30,500	55	89,200	21,100	24
Tennessee River						
Upper Tennessee including French Broad-Holston (code 0601)	6,610	6,350	4	6,660	50	1
Middle Tennessee including Hiwassee River (code 0602)	7,520	7,090	6	7,580	60	1
Middle Tennessee including Elk River (code 0603)	11,200	7,910	29	11,300	100	1
Lower Tennessee-Duck River (code 0604)	9,980	6,350	36	10,500	520	5
Ohio River after the confluence of Tennessee River (code 0514)	87,800	42,700	51	110,000	22,200	21

***** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.
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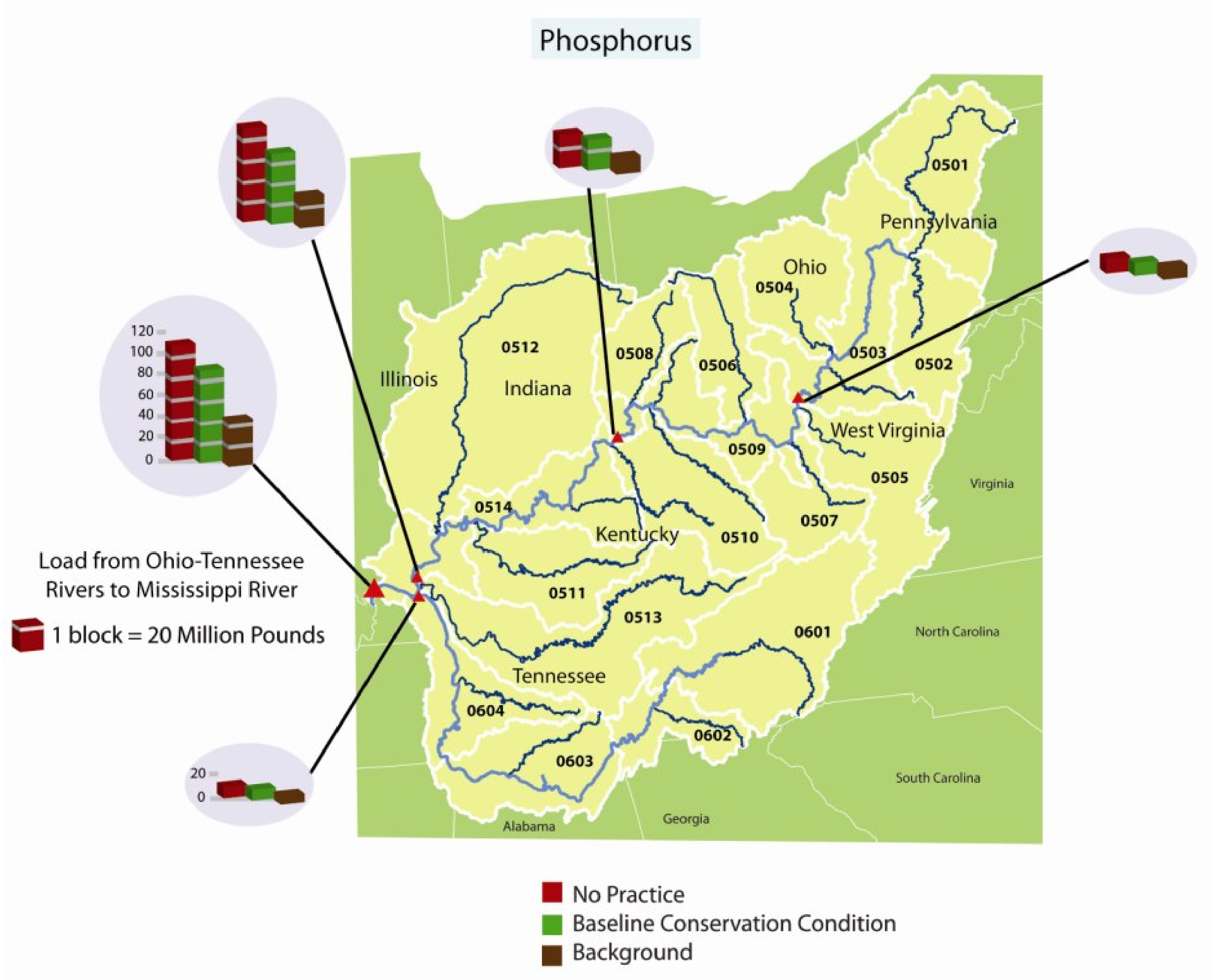
Figure 86. Estimates of average annual instream phosphorus loads for the baseline conservation condition compared to the no-practice scenario for the Ohio-Tennessee River Basin*



* Instream phosphorus loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 51.

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Atrazine

Although the full suite of pesticides was modeled for edge-of-field losses, atrazine was the only pesticide for which instream loads were assessed because it was the dominant contributor to mass loss of pesticide residues from farm fields and the primary contributor to environmental risk from pesticides in the region. First registered in the United States in 1959, atrazine is used to control broadleaf and grassy weeds. Cultivated cropland (primarily corn acres) was the only source for atrazine in the model simulations.

Baseline condition. Model simulation results show that about 266,000 pounds of atrazine are lost from farm fields (edge-of-field) through pathways that result in delivery to streams and rivers within the Ohio-Tennessee River Basin (table 52). Of this, about 244,000 pounds are delivered into rivers and streams each year, on average, under conditions represented by the baseline conservation condition (table 53).

About 69 percent of the atrazine delivered to rivers and streams from cultivated cropland in the region occurs in three subregions—

- The Wabash-Patoka-White River subregion (code 0512) with 46 percent,
- The Lower Ohio-Salt River subregion (code 0514) with 12 percent, and
- The Upper and Lower Cumberland River subregion (code 0513) with 11 percent.

Instream atrazine loads delivered to the Mississippi River, after accounting for instream deposition and transport processes, total about 178,000 pounds per year, averaged over the 47 years of weather as simulated in the model (table 54). Among the tributary subregions, the atrazine load at the outlet of the subregion is highest for the Wabash-Patoka-White River subregion (code 0512), which averages about 98,000 pounds at the outlet of the subregion.

Effects of conservation practices. Conservation practices—including Integrated Pest Management (IPM) techniques and practices—have reduced the delivery of atrazine from fields to rivers and streams by about 18 percent (table 53), on average. Within the subregions, reductions due to conservation practices range from a low of 10 percent for the Lower Ohio-Salt River subregion (code 0514) to a high of 35 percent for the Upper Ohio-Beaver-Little Kanawha River subregion (code 0503).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of atrazine from the Ohio-Tennessee River Basin to the Mississippi River by about 18 percent overall (table 54). Without conservation practices, the total atrazine load delivered to the Mississippi River would be larger by 40,000 pounds per year (table 54, fig. 87).

Table 52. Average annual atrazine source loads ***delivered to edge of field*** (APEX model output) from cultivated cropland for the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Percent
Allegheny and Monongahela River subregions (codes 0501, 0502)	6.3	2	0.009	8.2	1.9	24
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	2.6	1	0.004	3.9	1.4	35
Muskingum River subregion (code 0504)	7.3	3	0.006	9.2	1.9	21
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	10.9	4	0.005	13.9	3.0	22
Great Miami subregion (code 0508)	19.6	7	0.010	23.2	3.6	15
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	8.3	3	0.009	10.0	1.7	17
Licking-Kentucky and Green River subregions (codes 0510, 0511)	11.9	4	0.011	14.1	2.2	16
Wabash-Patoka-White River subregion (code 0512)	121.0	45	0.009	156.0	35.0	22
Upper and Lower Cumberland River subregion (code 0513)	29.0	11	0.029	34.1	5.1	15
Lower Ohio-Salt River subregion (code 0514)	33.5	13	0.017	37.2	3.7	10
subtotal	250.2	94	0.010	309.8	59.6	19
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	11.7	4	0.015	13.2	1.5	11
Lower Tennessee including Duck River subregion (code 0604)	4.5	2	0.007	6.2	1.7	28
subtotal	16.2	6	0.011	19.4	3.2	17
Regional total	266.4	100	0.010	329.2	62.8	19

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 53. Average annual atrazine source loads ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Percent
Allegheny and Monongahela River subregions (codes 0501, 0502)	5.6	2	0.008	7.2	1.6	22
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	2.2	1	0.003	3.3	1.1	35
Muskingum River subregion (code 0504)	6.1	2	0.005	7.7	1.6	21
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	9.8	4	0.004	12.4	2.7	21
Great Miami subregion (code 0508)	17.8	7	0.009	21.1	3.3	16
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	7.5	3	0.008	9.0	1.5	17
Licking-Kentucky and Green River subregions (codes 0510, 0511)	11.0	4	0.010	12.9	1.9	15
Wabash-Patoka-White River subregion (code 0512)	113.0	46	0.008	143.0	30.0	21
Upper and Lower Cumberland River subregion (code 0513)	26.2	11	0.026	30.7	4.5	15
Lower Ohio-Salt River subregion (code 0514)	30.3	12	0.015	33.6	3.4	10
subtotal	229.3	94	0.009	281.0	51.7	18
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	10.9	4	0.014	12.2	1.3	11
Lower Tennessee including Duck River subregion (code 0604)	4.1	2	0.007	5.8	1.6	28
subtotal	15.0	6	0.011	18.0	2.9	16
Regional total	244.4	100	0.009	299.0	54.6	18

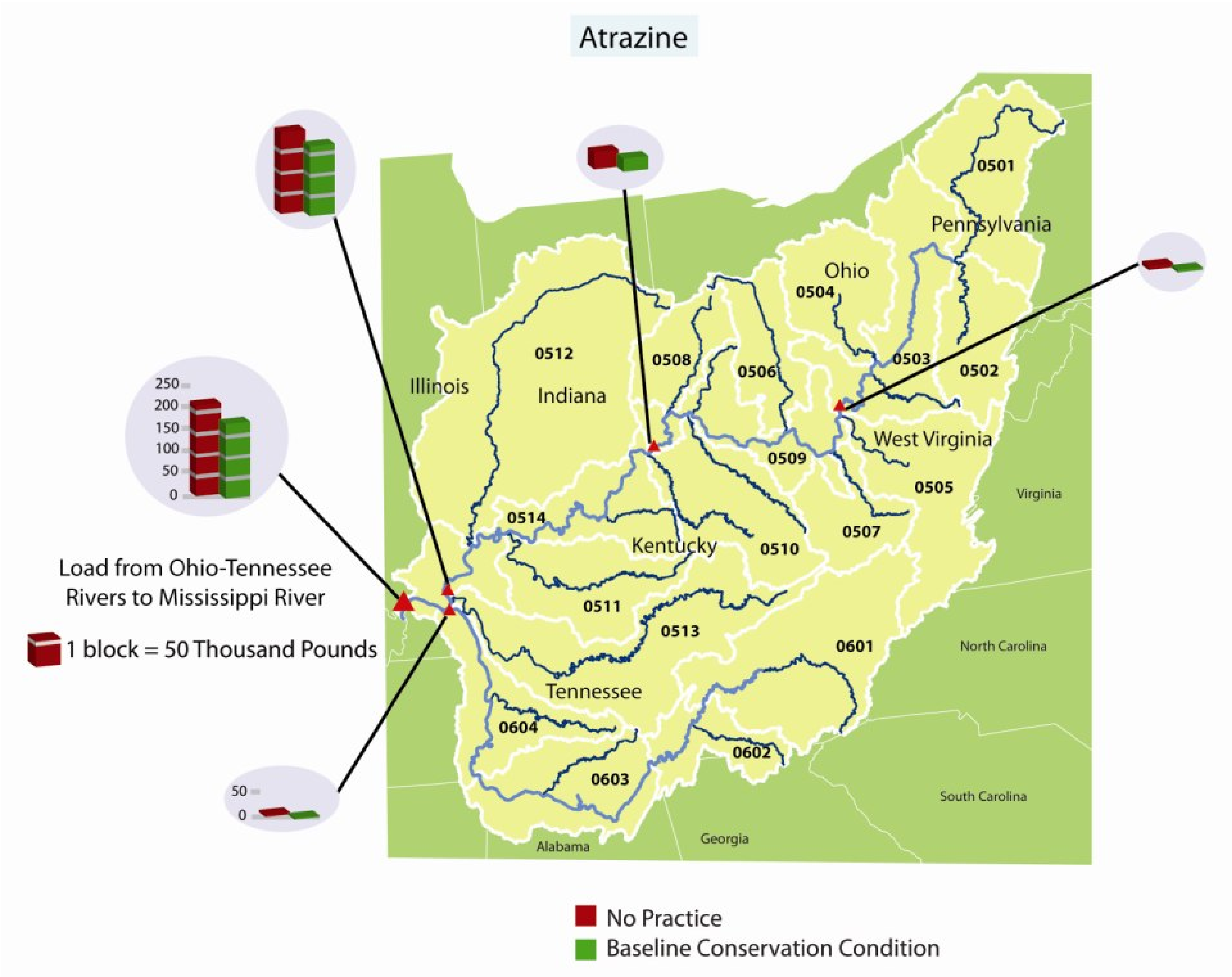
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 52 are due to the application of delivery ratios, which were used to simulate delivery of atrazine from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 54. Average annual ***instream atrazine loads*** for the Ohio-Tennessee River Basin

Subregions	Baseline conservation condition (1,000 pounds)	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Ohio River Basin--tributary subregions				
Allegheny River (code 0501)	4.2	5.4	1.2	23
Monongahela River (code 0502)	0.8	1.0	0.2	23
Muskingum River (code 0504)	3.9	5.0	1.0	21
Kanawha River (code 0505)	0.3	0.3	0.0	0
Scioto River (code 0506)	7.7	9.9	2.2	22
Guyandotte-Big Sandy River (code 0507)	0.1	0.1	0.0	17
Great Miami River (code 0508)	10.4	11.7	1.3	11
Licking-Kentucky River (code 0510)	0.3	0.3	0.0	5
Green River (code 0511)	8.8	10.6	1.9	17
Wabash-Patoka-White River (code 0512)	97.6	124.0	26.4	21
Upper and Lower Cumberland River (code 0513)	23.7	28.1	4.3	15
Ohio River--Outlets along mainstem				
Upper Ohio-Beaver-Little Kanawha (code 0503)	9.9	13.0	3.1	24
Middle Ohio-Raccoon-Little-Miami (code 0509)	34.5	42.2	7.7	18
Ohio River before the confluence of Tennessee River	162.0	199.0	37.0	19
Tennessee River				
Upper Tennessee including French Broad-Holston (code 0601)	0.0	0.0	0.0	54
Middle Tennessee including Hiwassee River (code 0602)	0.5	0.5	0.0	7
Middle Tennessee including Elk River (code 0603)	6.1	6.9	0.8	12
Lower Tennessee-Duck River (code 0604)	3.6	4.4	0.8	18
Ohio River after the confluence of Tennessee River (code 0514)	178.0	218.0	40.0	18

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Figure 87. Estimates of average annual instream atrazine loads for the baseline conservation condition compared to the no-practice scenario for the Ohio-Tennessee River Basin*



* Instream atrazine loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 54.

Assessment of Potential Water Quality Gains from Further Conservation Treatment

The field-level model results for the scenarios with additional erosion control practices and nutrient management (chapter 6) were used with the HUMUS/SWAT model to determine the potential for further reductions in loads delivered from cultivated cropland to rivers and streams and instream loads throughout the region with additional conservation treatment.

Percent reductions relative to the baseline conservation condition were estimated for each of two scenarios—

1. Treatment of the 6.0 million critical under-treated acres, which have a high need for additional treatment for one or more resource concern (24 percent of cropped acres in the region), and
2. Treatment of the 17.5 million acres with a high or moderate need for additional treatment for one or more resource concern, including the 6.0 million critical under-treated acres (70 percent of cropped acres in the region).

Acres not receiving treatment in the simulation retained baseline values. Thus, the distribution of under-treated acres within the region influences the extent to which individual subregions benefit from additional treatment, since additional treatment was simulated only for the under-treated acres. The distribution of under-treated acres within the Ohio-Tennessee River Basin is shown in chapter 5, table 30.

The subregion with the most undertreated acres is the Wabash-Patoka-White River subregion (code 0512), which also has the most cropped acres in the region. About 47 percent of the under-treated acres in the region are in this subregion, including 35 percent of the critical under-treated acres. About 64 percent of cropped acres in the subregion are under-treated, including 16 percent that are critically under-treated.

The Lower Ohio-Salt River subregion (code 0514) has the second-highest number of under-treated acres at 8 percent of the region's undertreated acres, including 12 percent of the critical under-treated acres. In this subregion, 77 percent of cropped acres are under-treated, including 41 percent that are critically under-treated.

Subregions with the highest percentages of cropped acres that are under-treated, however, tend to be the subregions where cultivated cropland acres are only a small share of the land cover, such as the Allegheny and Monongahela River subregions (codes 0501 and 0502) with 95 percent of cropped acres under-treated, the Lower Tennessee including Duck River subregion (code 0604) with 92 percent of cropped acres under-treated, and the Upper and Lower Cumberland River subregion (code 0513) with 88 percent of cropped acres under-treated.

Model simulations showed that if the 6.0 million **critical** under-treated acres were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the Ohio-Tennessee River Basin would be reduced by, relative to the baseline conservation condition (tables 55, 57, 59, and 61)—

- 60 percent for sediment,
- 19 percent for nitrogen,
- 26 percent for phosphorus, and
- 4 percent for atrazine.

Percent reductions were usually highest in subregions with the highest proportion of under-treated acres within the subregion.

Model simulations further showed that if **all** of the under-treated acres (an additional 11.5 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the watershed would be reduced, relative to the baseline conservation condition (tables 55, 57, 59, and 61)—

- 81 percent for sediment,
- 41 percent for nitrogen,
- 58 percent for phosphorus, and
- 11 percent for atrazine.

These reductions in loads delivered to rivers and streams from cultivated cropland would reduce the total loads delivered from the region to the Mississippi River. If the critical under-treated acres (6.0 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, total loads delivered to the Mississippi River from all sources would be reduced, relative to the baseline conservation condition (tables 56, 58, 60, and 62, and figs. 88 through 91)—

- 11 percent for sediment,
- 9 percent for nitrogen,
- 13 percent for phosphorus, and
- 4 percent for atrazine.

If **all** the under-treated acres (11.5 million additional acres) were fully treated with the appropriate soil erosion control and nutrient management practices, total loads delivered to the Mississippi River from all sources would be reduced, relative to the baseline conservation condition (tables 56, 58, 60, and 62, and figs. 88 through 91)—

- 15 percent for sediment,
- 20 percent for nitrogen,
- 31 percent for phosphorus, and
- 11 percent for atrazine.

As shown in table 56 and figure 88, sediment loads delivered from the region to the Mississippi River would be very close to "background" levels after additional conservation treatment of the under-treated acres, indicating that sediment contributions from cultivated cropland would be nearly negligible. The background scenario represents loads that would be expected if no acres in the watershed were cultivated. Background sediment loads delivered to the Mississippi River total 21.0 million tons (table 56) compared to 22.4 million tons delivered from all sources after treating all under-treated cropped acres with appropriate conservation

treatment, leaving only about 1.4 million tons originating from cultivated cropland.

Using similar calculations, if all under-treated acres were fully treated, nutrient loads originating from cultivated cropland delivered to the Mississippi River would be reduced to about 258 million pounds for nitrogen and 18 million pounds for phosphorus (tables 58 and 60). To reduce loads further would require additional conservation treatment of the remaining 7.5 million cropped acres with a low level of conservation treatment need, which would have a low per-acre benefit as shown in table 36.

Table 55. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **sediment source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Ohio-Tennessee River Basin

	Baseline conservation condition	Treatment of 6.0 million critical under-treated acres		Treatment of all 17.5 million under-treated acres	
Subregion	Average annual load (1,000 tons)	Average annual load (1,000 tons)	Percent reduction	Average annual load (1,000 tons)	Percent reduction
Allegheny and Monongahela River subregions (codes 0501, 0502)	1,039	154	85	77	93
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	361	113	69	47	87
Muskingum River subregion (code 0504)	832	165	80	86	90
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	476	259	46	120	75
Great Miami subregion (code 0508)	680	315	54	139	80
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	396	171	57	83	79
Licking-Kentucky and Green River subregions (codes 0510, 0511)	1,162	375	68	146	87
Wabash-Patoka-White River subregion (code 0512)	4,921	2,660	46	1,310	73
Upper and Lower Cumberland River subregion (code 0513)	1,031	547	47	135	87
Lower Ohio-Salt River subregion (code 0514)	2,535	770	70	373	85
subtotal	13,433	5,529	59	2,518	81
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	694	235	66	145	79
Lower Tennessee including Duck River subregion (code 0604)	636	204	68	95	85
subtotal	1,329	439	67	240	82
Regional total	14,762	5,968	60	2,757	81

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 56. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream sediment loads*** from all sources delivered to the Mississippi River from the Ohio-Tennessee River Basin

	Baseline conservation condition		Treatment of 6.0 million critical under-treated acres		Treatment of all 17.5 million under-treated acres	
Subregions	Average annual load from all sources (1,000 tons)	Average annual load from background sources* (1,000 tons)	Average annual load (1,000 tons)	Percent reduction	Average annual load (1,000 tons)	Percent reduction
Ohio River Basin--tributary subregions						
Allegheny River (code 0501)	1,860	1,550	1,600	14	1,580	15
Muskingum River (code 0504)	1,610	1,220	1,320	18	1,280	20
Scioto River (code 0506)	765	593	685	10	630	18
Great Miami River (code 0508)	513	214	363	29	287	44
Licking-Kentucky River (code 0510)	464	445	457	2	449	3
Green River (code 0511)	911	473	612	33	535	41
Wabash-Patoka-White River (code 0512)	3,150	1,190	2,210	30	1,800	43
Upper and Lower Cumberland River (code 0513)	1,620	1,300	1,470	9	1,350	17
Ohio River--Outlets along mainstem						
Upper Ohio-Beaver-Little Kanawha (code 0503)	8,580	8,070	8,230	4	8,170	5
Middle Ohio-Raccoon-Little-Miami (code 0509)	12,700	11,800	12,200	4	12,000	6
Ohio River before the confluence of Tennessee River	21,400	16,800	18,900	12	18,000	16
Tennessee River						
Middle Tennessee including Elk River (code 0603)	581	493	522	10	513	12
Lower Tennessee-Duck River (code 0604)	617	470	529	14	498	19
Ohio River after the confluence of Tennessee River (code 0514)	26,300	21,000	23,400	11	22,400	15

* "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment. CEAP sample size was too small to report results of additional conservation treatment in 5 subregions: 1) Monongahela River (code 0502), 2) Kanawha River (code 0505), 3) Guyandotte-Big Sandy River (code 0507), 4) Upper Tennessee including French Broad-Holston (code 0601), and 5) Middle Tennessee including Hiwassee River (code 0602).

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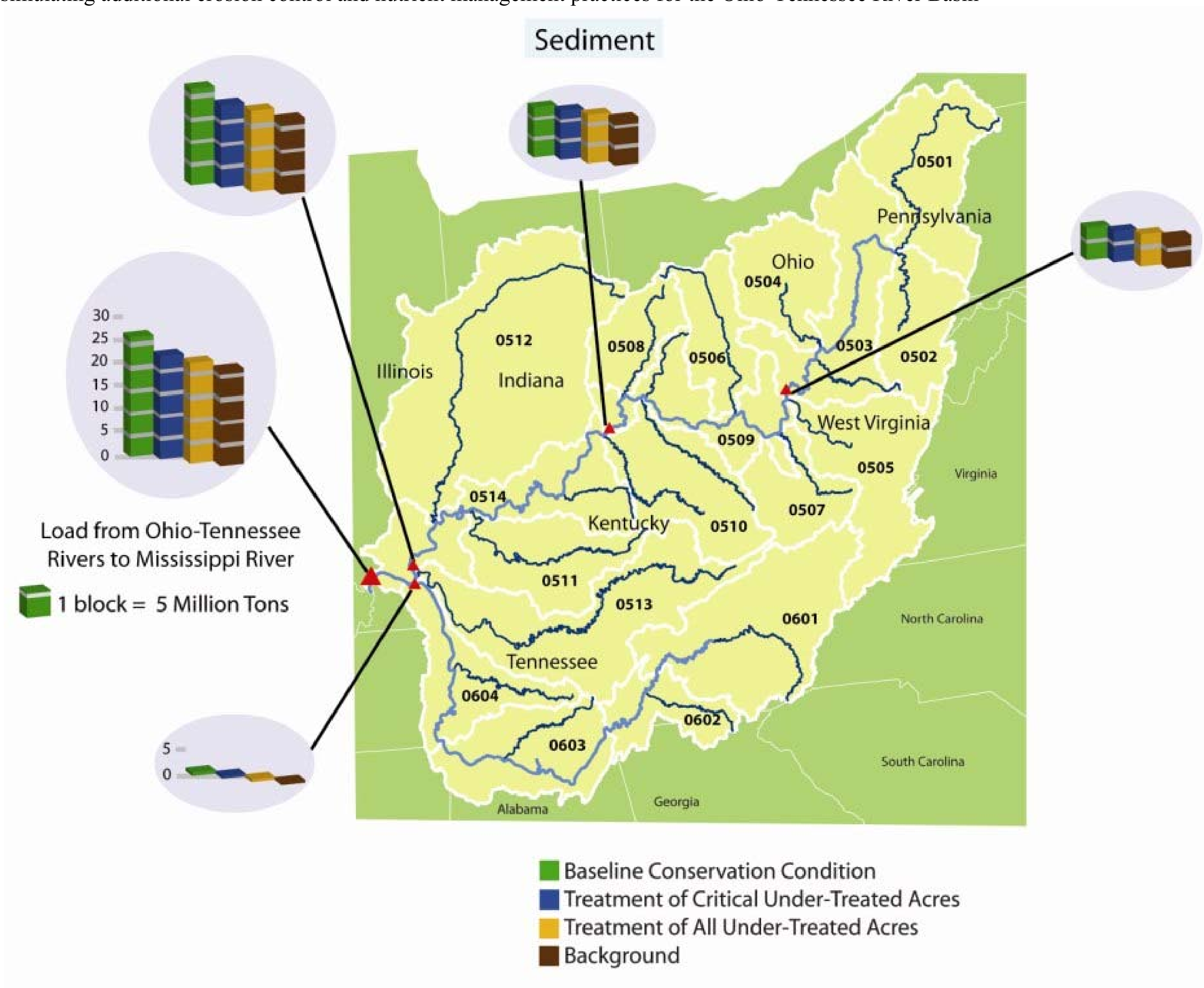
Figure 88. Estimates of average annual instream sediment loads* for the baseline conservation condition compared to two scenarios simulating additional erosion control and nutrient management practices for the Ohio-Tennessee River Basin



* Instream sediment loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 56.

Note: “Background sources” represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. “Background” loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Note: Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

Table 57. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **nitrogen source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Ohio-Tennessee River Basin

	Baseline conservation condition	Treatment of 6.0 million critical under-treated acres		Treatment of all 17.5 million under-treated acres	
Subregion	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Allegheny and Monongahela River subregions (codes 0501, 0502)	17,463	10,970	37	9,740	44
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	14,115	9,680	31	8,490	40
Muskingum River subregion (code 0504)	21,503	17,000	21	13,000	40
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	34,682	31,612	9	23,785	31
Great Miami subregion (code 0508)	36,040	29,200	19	21,700	40
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	14,471	12,200	16	8,520	41
Licking-Kentucky and Green River subregions (codes 0510, 0511)	23,612	17,160	27	11,860	50
Wabash-Patoka-White River subregion (code 0512)	233,220	201,000	14	143,000	39
Upper and Lower Cumberland River subregion (code 0513)	26,358	22,500	15	12,900	51
Lower Ohio-Salt River subregion (code 0514)	41,066	27,100	34	20,700	50
subtotal	462,530	378,422	18	273,695	41
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	24,645	16,876	32	14,071	43
Lower Tennessee including Duck River subregion (code 0604)	13,457	10,700	20	6,320	53
subtotal	38,102	27,576	28	20,391	46
Regional total	500,632	405,998	19	294,086	41

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

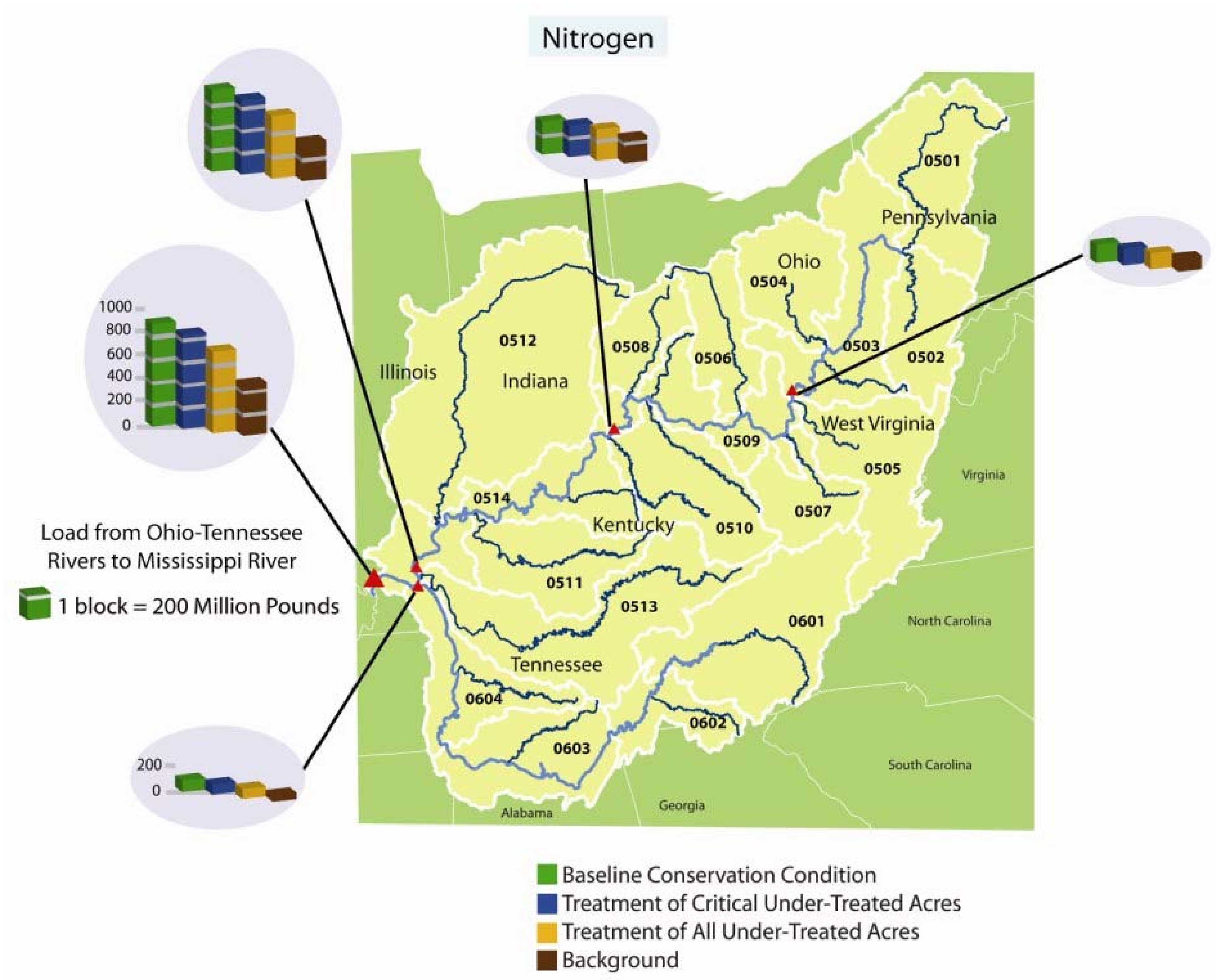
Table 58. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream nitrogen loads*** from all sources delivered to the Mississippi River from the Ohio-Tennessee River Basin

	Baseline conservation condition		Treatment of 6.0 million critical under-treated acres		Treatment of all 17.5 million under-treated acres	
Subregions	Average annual load from all sources (1,000 pounds)	Average annual load from background sources* (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Ohio River Basin--tributary subregions						
Allegheny River (code 0501)	63,014	48,918	57,100	9	56,100	11
Muskingum River (code 0504)	46,143	25,729	41,600	10	37,800	18
Scioto River (code 0506)	43,106	12,268	40,600	6	33,700	22
Great Miami River (code 0508)	25,982	10,239	22,600	13	19,600	25
Licking-Kentucky River (code 0510)	18,480	17,408	18,300	1	17,800	4
Green River (code 0511)	42,555	22,468	36,700	14	32,300	24
Wabash-Patoka-White River (code 0512)	270,556	54,776	239,000	12	186,000	31
Upper and Lower Cumberland River (code 0513)	65,723	41,063	61,900	6	52,600	20
Ohio River--Outlets along mainstem						
Upper Ohio-Beaver-Little Kanawha (code 0503)	195,140	150,586	185,000	5	179,000	8
Middle Ohio-Raccoon-Little-Miami (code 0509)	334,679	230,857	317,000	5	298,000	11
Ohio River before the confluence of Tennessee River	728,810	352,293	662,000	9	578,000	21
Tennessee River						
Middle Tennessee including Elk River (code 0603)	73,500	51,200	67,100	9	64,700	12
Lower Tennessee-Duck River (code 0604)	102,000	66,500	93,000	9	86,300	15
Ohio River after the confluence of Tennessee River (code 0514)	897,082	457,965	816,000	9	716,000	20

* “Background sources” represent loads that would be expected if no acres in the watershed were cultivated..

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment. CEAP sample size was too small to report results of additional conservation treatment in 5 subregions: 1) Monongahela River (code 0502), 2) Kanawha River (code 0505), 3) Guyandotte-Big Sandy River (code 0507), 4) Upper Tennessee including French Broad-Holston (code 0601), and 5) Middle Tennessee including Hiwassee River (code 0602).

Figure 89. Estimates of average annual instream nitrogen loads* for the baseline conservation condition compared to two scenarios simulating additional erosion control and nutrient management practices for the Ohio-Tennessee River Basin



* Instream nitrogen loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 58.

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Note: Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

Table 59. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **phosphorus source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Ohio-Tennessee River Basin

Subregion	Baseline conservation condition: Average annual load (1,000 pounds)	Treatment of 6.0 million critical under-treated acres: Average annual load (1,000 pounds)	Treatment of 6.0 million critical under-treated acres: Percent reduction	Treatment of all 17.5 million under-treated acres: Average annual load (1,000 pounds)	Treatment of all 17.5 million under-treated acres: Percent reduction
Allegheny and Monongahela River subregions (codes 0501, 0502)	1,956	1,026	48	913	53
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	1,023	705	31	539	47
Muskingum River subregion (code 0504)	1,905	1,200	37	1,000	48
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	3,355	2,889	14	1,501	55
Great Miami subregion (code 0508)	3,052	2,600	15	1,450	52
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	1,916	1,480	23	808	58
Licking-Kentucky and Green River subregions (codes 0510, 0511)	3,330	2,325	30	1,263	62
Wabash-Patoka-White River subregion (code 0512)	22,348	18,500	17	10,200	54
Upper and Lower Cumberland River subregion (code 0513)	3,784	2,800	26	1,310	65
Lower Ohio-Salt River subregion (code 0514)	5,820	3,500	40	1,930	67
subtotal	48,489	37,025	24	20,914	57
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	4,084	2,128	48	1,253	69
Lower Tennessee including Duck River subregion (code 0604)	2,068	1,220	41	545	74
subtotal	6,152	3,348	46	1,798	71
Regional total	54,640	40,373	26	22,712	58

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

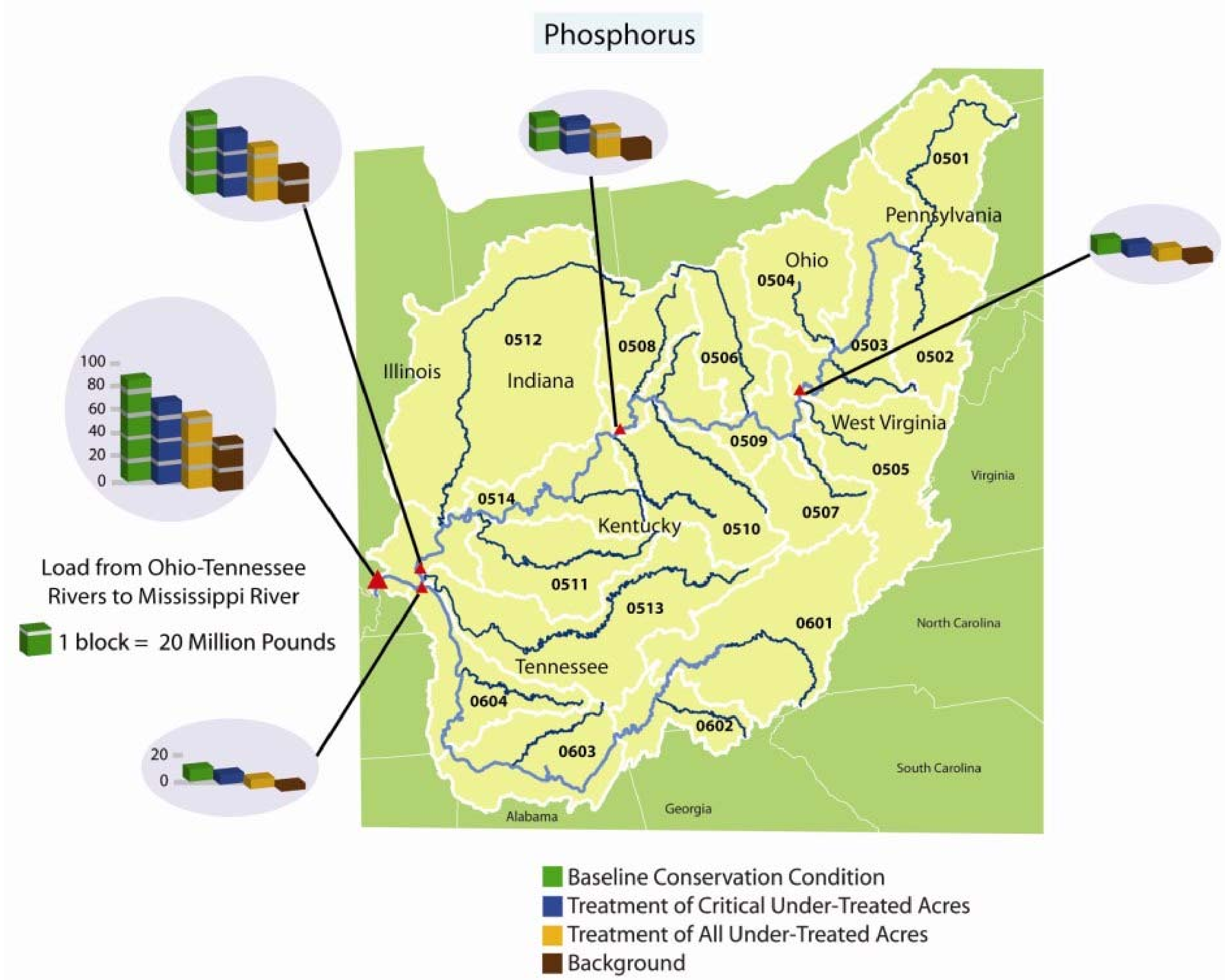
Table 60. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream phosphorus loads*** from all sources delivered to the Mississippi River from the Ohio-Tennessee River Basin

	Baseline conservation condition		Treatment of 6.0 million critical under-treated acres		Treatment of all 17.5 million under-treated acres	
Subregions	Average annual load from all sources (1,000 pounds)	Average annual load from background sources* (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Ohio River Basin--tributary subregions						
Allegheny River (code 0501)	4,500	3,360	3,860	14	3,790	16
Muskingum River (code 0504)	4,180	2,540	3,550	15	3,370	19
Scioto River (code 0506)	3,950	1,130	3,520	11	2,280	42
Great Miami River (code 0508)	4,180	1,750	3,810	9	2,850	32
Licking-Kentucky River (code 0510)	1,930	1,820	1,900	2	1,850	4
Green River (code 0511)	5,470	2,660	4,610	16	3,690	33
Wabash-Patoka-White River (code 0512)	24,800	4,670	21,100	15	13,300	46
Upper and Lower Cumberland River (code 0513)	9,180	5,680	8,230	10	6,780	26
Ohio River--Outlets along mainstem						
Upper Ohio-Beaver-Little Kanawha (code 0503)	13,700	10,300	12,400	9	12,000	12
Middle Ohio-Raccoon-Little-Miami (code 0509)	28,600	18,400	26,100	9	22,900	20
Ohio River before the confluence of Tennessee River	68,100	30,500	59,200	13	46,000	32
Tennessee River						
Middle Tennessee including Elk River (code 0603)	11,200	7,910	9,720	13	9,030	19
Lower Tennessee-Duck River (code 0604)	9,980	6,350	8,340	16	7,390	26
Ohio River after the confluence of Tennessee River (code 0514)	87,800	42,700	76,100	13	60,500	31

* “Background sources” represent loads that would be expected if no acres in the watershed were cultivated..

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment. CEAP sample size was too small to report results of additional conservation treatment in 5 subregions: 1) Monongahela River (code 0502), 2) Kanawha River (code 0505), 3) Guyandotte-Big Sandy River (code 0507), 4) Upper Tennessee including French Broad-Holston (code 0601), and 5) Middle Tennessee including Hiwassee River (code 0602).

Figure 90. Estimates of average annual instream phosphorus loads* for the baseline conservation condition compared to two scenarios simulating additional erosion control and nutrient management practices for the Ohio-Tennessee River Basin



* Instream phosphorus loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 60.

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Note: Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

Table 61. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **atrazine source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Ohio-Tennessee River Basin

	Baseline conservation condition	Treatment of 6.0 million critical under-treated acres		Treatment of all 17.5 million under-treated acres	
Subregion	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Allegheny and Monongahela River subregions (codes 0501, 0502)	5.6	4.6	19	4.4	22
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	2.2	1.9	12	1.7	20
Muskingum River subregion (code 0504)	6.1	5.6	8	5.2	14
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)*	9.8	9.6	2	8.5	13
Great Miami subregion (code 0508)	17.8	16.9	5	15.5	13
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	7.5	7.1	6	6.6	13
Licking-Kentucky and Green River subregions (codes 0510, 0511)	11.0	10.3	6	9.7	11
Wabash-Patoka-White River subregion (code 0512)	113.0	109.0	4	101.0	11
Upper and Lower Cumberland River subregion (code 0513)	26.2	25.3	3	22.9	12
Lower Ohio-Salt River subregion (code 0514)	30.3	28.6	5	26.9	11
subtotal	229.3	218.8	5	202.5	12
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	10.9	10.7	2	10.7	2
Lower Tennessee including Duck River subregion (code 0604)	4.1	4.0	3	3.8	8
subtotal	15.0	14.7	2	14.5	4
Regional total	244.4	233.5	4	217.0	11

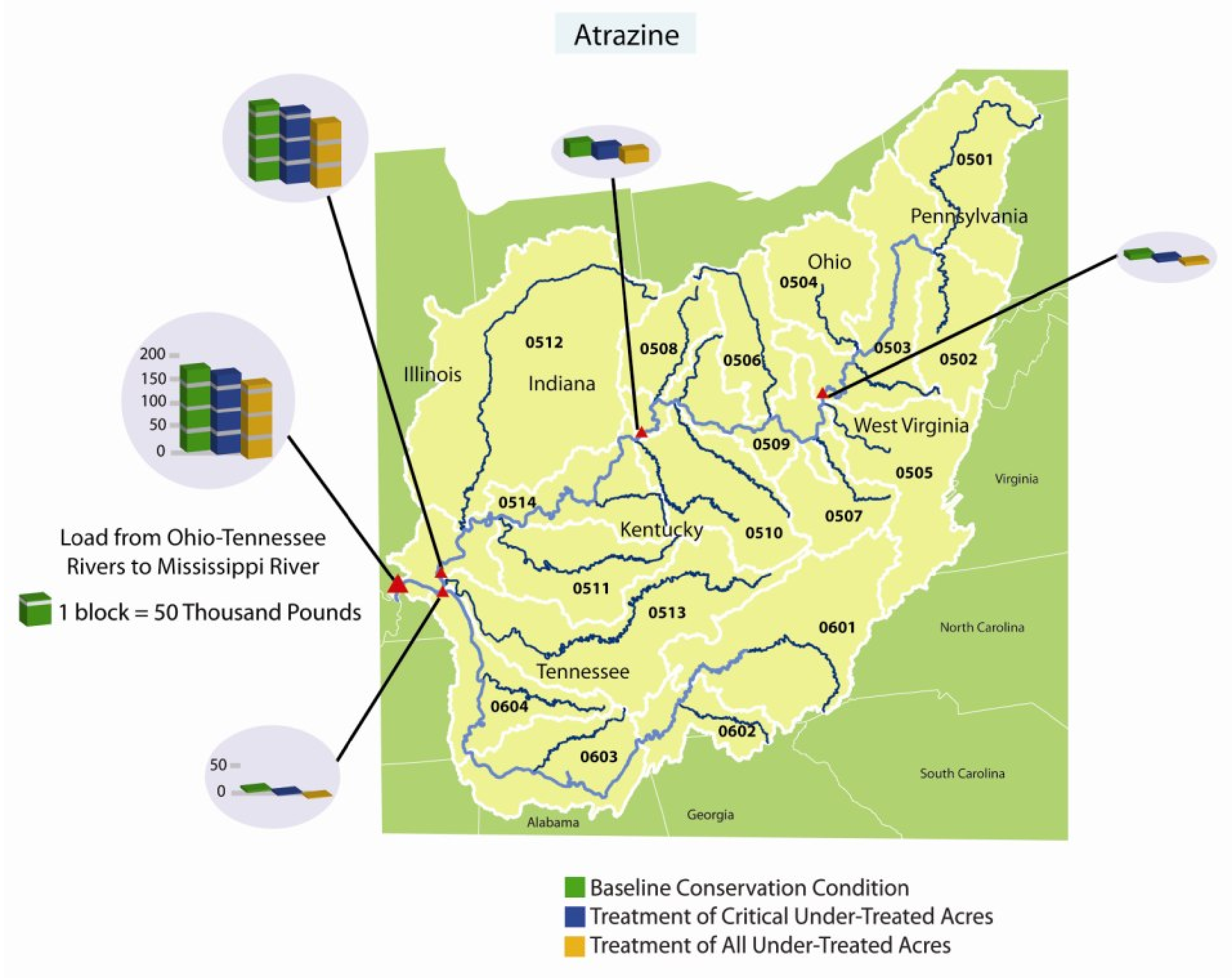
Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.
* The bulk of cultivated cropland in these three subregions is found in the Scioto River subregion.

Table 62. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream atrazine loads*** delivered to the Mississippi River from the Ohio-Tennessee River Basin

	Baseline conservation condition	Treatment of 6.0 million critical under-treated acres		Treatment of all 17.5 million under-treated acres	
Subregions	Average annual load from all sources (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Ohio River Basin--tributary subregions					
Allegheny River (code 0501)	4.2	3.4	19	3.3	21
Muskingum River (code 0504)	0.8	0.6	20	0.6	23
Scioto River (code 0506)	0.3	0.3	5	0.3	12
Great Miami River (code 0508)	0.1	0.1	6	0.1	6
Licking-Kentucky River (code 0510)	0.3	0.3	0	0.3	0
Green River (code 0511)	8.8	8.2	7	7.7	12
Wabash-Patoka-White River (code 0512)	97.6	94.7	3	87.6	10
Upper and Lower Cumberland River (code 0513)	23.7	23.1	3	20.8	12
Ohio River--Outlets along mainstem					
Upper Ohio-Beaver-Little Kanawha (code 0503)	9.9	8.5	14	8.0	19
Middle Ohio-Raccoon-Little-Miami (code 0509)	34.5	32.2	7	29.5	14
Ohio River before the confluence of Tennessee River	162.0	155.0	4	144.0	11
Tennessee River					
Middle Tennessee including Elk River (code 0603)	0.0	0.0	0	0.0	0
Lower Tennessee-Duck River (code 0604)	3.6	3.6	0	3.6	2
Ohio River after the confluence of Tennessee River (code 0514)	178.0	171.0	4	158.0	11

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment. CEAP sample size was too small to report results of additional conservation treatment in 5 subregions: 1) Monongahela River (code 0502), 2) Kanawha River (code 0505), 3) Guyandotte-Big Sandy River (code 0507), 4) Upper Tennessee including French Broad-Holston (code 0601), and 5) Middle Tennessee including Hiwassee River (code 0602).

Figure 91. Estimates of average annual instream atrazine loads* for the baseline conservation condition compared to two scenarios simulating additional erosion control and nutrient management practices for the Ohio-Tennessee River Basin



* Instream atrazine loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 62.

Note: Critical under-treated acres have a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

Chapter 8
Summary of Findings

Field Level Assessment

Evaluation of Practices in Use

The first Federal conservation efforts on cropland were focused primarily on water management and soil erosion control. Structural practices such as waterways, terraces, and diversions were installed along with supporting practices such as contour farming and stripcropping. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres—highly erodible land. This legislation created the Conservation Reserve Program as a mechanism for establishing long-term conserving cover on the most erodible cropland through multi-year contracts with landowners. More recently, the focus has shifted from soil conservation and sustainability to a broader goal of reducing all pollution impacts associated with agricultural production. Prominent among new concerns are the environmental effects of nutrient and pesticide export from farm fields.

The application of conservation practices in the Ohio-Tennessee River Basin closely reflects this history of Federal conservation programs and technical assistance. An assessment of the extent of conservation practice use, based on a farmer survey representing practice use and farming activities for the period 2003–06, found the following:

- Structural practices for controlling water erosion are in use on 40 percent of cropped acres. On the 27 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 59 percent of those acres.
- Reduced tillage is common in the region; 93 percent of the cropped acres meet criteria for either no-till (52 percent) or mulch till (41 percent). All but 4 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- Two thirds of cropped acres are gaining soil organic carbon. An additional 20 percent of cropped acres are considered to be "maintaining" soil organic carbon (average annual loss less than 100 pounds per acre). Overall, 86 percent of cropped acres are maintaining or enhancing soil organic carbon.
- Producers use either residue and tillage management practices or structural practices, or both, on 98 percent of the acres.
- While most acres have evidence of some nitrogen or phosphorus management, the majority of the acres in the region lack consistent use of appropriate rates, timing, *and* method of application on each crop in every year of production.
    - Appropriate timing of nitrogen applications is in use on about 64 percent of the acres for all crops in the rotation.
    - About 39 percent of cropped acres meet criteria for appropriate nitrogen application rates for all crops in the rotation.
    - Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production, however, are in use on only about 17 percent of cropped acres.
    - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 21 percent of the acres on all crops during every year of production.
    - Only about 10 percent of cropped acres meet full nutrient management criteria for *both* phosphorus and nitrogen management, including acres not receiving nutrient applications.
- During the 2003–06 period of data collection, cover crops were used on about 2 percent of the acres in the region.
- An Integrated Pest Management (IPM) indicator showed that only about 5 percent of the acres were being managed at a relatively high level of IPM.
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of about 776,400 acres in the region, of which 70 percent is highly erodible land.

Effects of Conservation Practices

Model simulation results show that, for cropped acres in the region, *on average* conservation practices have—

- Reduced surface water flow from fields by 8 percent, re-routing most of the water to subsurface flow pathways;
- Reduced wind erosion by 60 percent, from 0.05 ton per acre without conservation practices to 0.02 ton per acre with conservation practices;
- Reduced sediment loss from fields by 52 percent, from 3.3 tons per acre without conservation practices to 1.6 tons per acre with conservation practices;
- Decreased the percentage of acres that are losing soil organic carbon from 43 percent to 34 percent;
- Reduced total nitrogen loss (volatilization, denitrification, surface runoff, and subsurface flow losses) from fields by 17 percent, from 51 pounds per acre without conservation practices to 43 pounds per acre with conservation practices:
    - reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 35 percent, from 20.5 pounds per acre without conservation practices to 13.2 pounds per acre with conservation practices;
    - reduced nitrogen loss in subsurface flows by 11 percent, from 21.6 pounds per acre without conservation practices to 19.2 pounds per acre with conservation practices;
- Reduced total phosphorus loss from fields by 33 percent, from 6.9 pounds per acre without conservation practices to 4.6 pounds per acre with conservation practices; and

- Reduced pesticide loss from fields to surface water, resulting in a 29-percent reduction in edge-of-field pesticide risk (all pesticides combined) for aquatic ecosystems and a 19-percent reduction in edge-of-field pesticide risk for humans.

The relatively low reductions in nitrogen loss in subsurface flows result from a combination of incomplete nutrient management and the re-routing of surface water runoff to subsurface flows by water erosion control practices on some acres in the region. On 42 percent of the cropped acres, nitrogen losses in subsurface flows increase as a result of conservation practices, although most increases are small. Structural erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil.

While conservation practices have been effective in reducing phosphorus loss from fields, phosphorus loss to surface runoff in the region remains high. With the conservation practices in use as represented by the baseline conservation condition, phosphorus loss exceeds 4 pounds per acre per year, on average, for about 35 percent of cropped acres in this region. This is, in part, because of high levels of soluble phosphorus loss, which averages 2.4 pounds per acre per year in the baseline. Soluble phosphorus loss with surface water runoff and lateral flow (including discharge to drainage ditches) was the dominant loss pathway for 57 percent of cropped acres in the region.

For land in long-term conserving cover (776,400 acres), soil erosion and sediment loss have been almost completely eliminated. Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 80 percent, total phosphorus loss has been reduced by 93 percent, and soil organic carbon has been increased by an average of 497 pounds per acre per year.

Conservation Treatment Needs

The adequacy of conservation practices in use in the Ohio-Tennessee River Basin for the time period 2003–06 was evaluated to identify conservation treatment needs for four resource concerns:

- sediment loss from fields,
- nitrogen lost with surface runoff (attached to sediment and in solution),
- nitrogen loss in subsurface flows, and
- phosphorus lost to surface water (includes soluble phosphorus in lateral flow)

Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres to reduce field-level losses to acceptable levels. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Under-treated acres were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Three levels of treatment need were identified:

- Acres with a "high" level of need for conservation treatment consist of the most critical under-treated acres in the region. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients.
- Acres with a "moderate" level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability and/or have more conservation practice use than acres with a high level of need. The treatment level required is not necessarily less, although it can be, but rather the sediment and nutrient losses are lower and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment.
- Acres with a "low" level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. While gains can be obtained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

The most critical concern in the region is excessive loss of phosphorus from fields. About 20 percent of the acres in the region have a "high" need for additional nutrient management to address this concern, and an additional 43 percent have a "moderate" need. The proportion of cropped acres with a "high" or "moderate" need for additional conservation treatment for other resource concerns was determined to be—

- 25 percent for sediment loss (13.5 percent with a "high" need for treatment),
- 29 percent for nitrogen loss with runoff (12 percent with a "high" need for treatment), and
- 17 percent for nitrogen loss in subsurface flows (2 percent with a "high" need for treatment).

Some acres require additional treatment for only one of the four resource concerns, while other acres require additional treatment for two or more resource concerns. After accounting for acres that need treatment for multiple resource concerns, the evaluation of treatment needs for the Ohio-Tennessee River Basin determined the following:

- 24 percent of cropped acres (6.0 million acres) have a "high" level of need for additional conservation treatment for one or more resource concerns.
- 46 percent of cropped acres (11.5 million acres) have a "moderate" level of need for additional conservation treatment for one or more resource concerns.
- 30 percent of cropped acres (7.5 million acres) have a "low" level of need for additional treatment and are considered to be adequately treated.

Acres with a “high” level of need for conservation treatment lose (per acre per year, on average)—
- 4.3 tons of sediment by water erosion,
- 7.7 pounds of phosphorus,
- 25 pounds of nitrogen with surface runoff, and
- 24 pounds of nitrogen in subsurface flows.

Acres with a “moderate” level of need for conservation treatment lose (per acre per year, on average)—
- 0.9 ton of sediment by water erosion,
- 4.5 pounds of phosphorus,
- 11 pounds of nitrogen with surface runoff, and
- 20 pounds of nitrogen in subsurface flows.

Acres with a “low” level of need for conservation treatment lose (per acre per year, on average)—
- 0.5 ton of sediment by water erosion,
- 1.9 pounds of phosphorus,
- 7 pounds of nitrogen with surface runoff, and
- 14 pounds of nitrogen in subsurface flows.

About half of the under-treated acres are under-treated for only one of the four resource concerns:
- 42 percent of under-treated acres are under-treated only for phosphorus runoff,
- 6 percent of under-treated acres are under-treated only for nitrogen leaching, and
- about 1.5 percent of under-treated acres are under-treated either for sediment loss or nitrogen lost with surface runoff.

One-fourth of under-treated acres need additional treatment for the three resource concerns related to runoff. Another 10 percent need treatment for nitrogen leaching <u>and</u> phosphorus runoff. Only about 7 percent of under-treated acres were determined to be under-treated for all four resource concerns.

Critical under-treated acres are disproportionately high in seven subregions. The most striking are the Allegheny and Monongahela River subregions and the Muskingum River subregion, where 70 and 50 percent of the acres are critically under-treated, respectively.

In contrast, the Wabash-Patoka-White River subregion has a sharply disproportionately lower number of under-treated acres. This subregion has 52 percent of the cropped acres in the region, but only 35 percent of the critical acres and 47 percent of undertreated acres. Only 16 percent of the cropped acres in this subregion are critically under-treated.

Simulation of Additional Conservation Treatment

Additional conservation treatment was simulated for: 1) the 6.0 million acres in the region with a “high” treatment need (critical under-treated acres), and 2) all 17.5 million under-treated acres. Two levels of treatment were simulated for each set of acres:
- *Treatment with additional erosion control practices*, which consisted of adding in-field practices to control overland flow (terraces, contouring, or stripcropping) for acres without overland flow control practices and having a slope of more than 2 percent, and adding edge-of-field buffering or filtering practices to all acres without edge-of-field practices.
- *Treatment with nutrient management in addition to erosion control practices*, which was modeled by adjusting the commercial fertilizer and manure applications to simulate the appropriate rate of application, the appropriate timing of application, and use of the appropriate application method.

Model simulations demonstrated that sediment and nitrogen losses with surface runoff could be effectively controlled in the region with additional erosion control practices. However, model simulations also showed that a suite of practices that includes both soil erosion control and consistent nutrient management is *required* to simultaneously address soil erosion *and* nutrient loss through all loss pathways. Treatment with combinations of soil erosion control practices and nutrient management makes applied nutrients more available for use by crops and thus significantly reduces the re-routing of soluble nitrogen and phosphorus to subsurface loss pathways.

Treatment of the 6.0 million acres with a “high” need for additional treatment would achieve the following gains ***for the region as a whole*** *when both soil erosion control practices and nutrient management practices were applied where needed*:
- Sediment loss from fields would average 0.63 ton per acre per year, compared to the baseline conservation condition average of 1.59 tons per acre per year (a 61-percent reduction).
- Nitrogen lost from the field with surface runoff (attached to sediment and in solution) would average 8.7 pounds per acre per year, compared to the baseline conservation condition average of 13.2 pounds per acre per year (a 34-percent reduction).
- Nitrogen loss from the field in subsurface flows would average 16.4 pounds per acre per year, compared to the baseline conservation condition average of 19.2 pounds per acre per year (a 15-percent reduction).
- Total phosphorus loss, most of which is lost to surface water, would average 3.2 pounds per acre per year, compared to 4.6 pounds per acre per year for the baseline conservation condition (a 31-percent reduction).
- Environmental risk from the loss of pesticide residues would be reduced about 3 percent.

Treatment of all 17.5 million under-treated acres would achieve the following gains ***for the region as a whole*** *when both soil erosion control practices and nutrient management practices were applied where needed*:
- Sediment loss from fields would average 0.27 ton per acre per year, compared to the baseline conservation condition average of 1.59 tons per acre per year (an 83-percent reduction).

- Nitrogen lost from the field with surface runoff (attached to sediment and in solution) would average 5.6 pounds per acre per year, compared to the baseline conservation condition average of 13.2 pounds per acre per year (a 58-percent reduction).
- Nitrogen loss from the field in subsurface flows would average 12 pounds per acre per year, compared to the baseline conservation condition average of 19 pounds per acre per year (a 37-percent reduction).
- Total phosphorus loss, most of which is lost to surface water, would average 1.8 pounds per acre per year, compared to 4.6 pounds per acre per year for the baseline conservation condition (a 61-percent reduction).
- Environmental risk from the loss of pesticide residues would be reduced about 11 percent.

Not all acres get the same benefit from conservation treatment. The more vulnerable acres, such as highly erodible land and soils prone to leaching, inherently lose more sediment and/or nutrients, and therefore greater benefit can be attained with conservation treatment. The gains in efficiency by first treating the 6.0 million critical under-treated acres would—

- reduce sediment loss an average of 4 tons per acre per year on those acres, compared to 0.77 ton per acre per year for additional treatment of the remaining 11.5 million under-treated acres and only 0.42 ton per acre per year for treatment of the 7.5 million adequately treated acres, on average;
- reduce total nitrogen loss an average of 33 pounds per acre per year on those acres, compared to 19 pounds per acre per year for additional treatment of the remaining 11.5 million under-treated acres and only 10 pounds per acre per year for treatment of the 7.5 million adequately treated acres, on average; and
- reduce total phosphorus loss an average of 5.9 pounds per acre per year on those acres, compared to 3.0 pounds per acre per year for additional treatment of the remaining 11.5 million under-treated acres and only 0.8 pound per acre per year for treatment of the 7.5 million adequately treated acres, on average.

Conservation Practice Effects on Water Quality

Reductions in field-level losses due to conservation practices, including land in long-term conserving cover, translate into improvements in water quality in streams and rivers in the region. Transport of sediment, nutrients, and pesticides from farm fields to streams and rivers involves a variety of processes and time-lags, and not all of the potential pollutants leaving fields contribute to instream loads.

Cultivated cropland represents about 21 percent of the land base in the Ohio-Tennessee River Basin. At the 2003–06 level of conservation practice use, cultivated cropland delivered a disproportionate amount of sediment and nutrients to rivers and streams and ultimately to the Mississippi River. Of the total loads delivered to rivers and streams from all sources, cultivated cropland is the source for 53 percent of the sediment, 49 percent of the nitrogen, and 48 percent of the phosphorus.

Figures 92, 93, and 94 summarize the extent to which conservation practices on cultivated cropland acres have reduced, and can further reduce, sediment, nitrogen, and phosphorus loads in the Ohio-Tennessee River Basin, on the basis of the model simulations.

In each figure, the top map shows delivery from cultivated cropland to rivers and streams within the basin and the bottom map shows delivery from all sources to the Mississippi River after accounting for losses and gains through instream processes during transport through the Ohio-Tennessee River system.

The effects of practices in use during 2003–06 are seen by contrasting loads for the baseline conservation condition to loads for the no-practice scenario.

The effects of additional conservation treatment on loads are seen by contrasting the loads for the baseline condition to either—

1. loads for treatment of acres with a "high" level of treatment need (6.0 million critical under-treated acres), or
2. loads for treatment of all under-treated acres (17.5 million acres with either a "high" or "moderate" level of treatment need).

Background levels, representing loads that would be expected if no acres in the watershed were cultivated, are also shown in the bar charts. These estimates simulate a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. Background loads also include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

Sediment loss

In figure 92, the top map shows that the use of conservation practices has reduced ***sediment loads delivered from cropland to rivers and streams*** within the basin by 55 percent from conditions that would be expected without conservation practices. Application of additional conservation practices would reduce baseline sediment loads delivered to rivers and streams by 60 percent by treating acres with a "high" level of treatment need. Treating ALL under-treated acres (acres with either a "high" or "moderate" need for treatment) would reduce baseline sediment loads delivered to rivers and streams within the basin by 81 percent.

The bottom map shows that the use of conservation practices on cropland has reduced ***sediment loads delivered to the Mississippi River from all sources*** by 16 percent from conditions that would be expected without conservation practices. Application of additional conservation practices would reduce baseline sediment loads delivered to the Mississippi River by 11 percent by treating acres with a

“high” level of treatment need. Treating ALL under-treated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline sediment loads delivered to the Mississippi River by 15 percent.

Total nitrogen loss

In figure 93, the top map shows that the use of conservation practices has reduced ***total nitrogen loads delivered from cropland to rivers and streams*** within the basin by 26 percent from conditions that would be expected without conservation practices. Application of additional conservation practices would reduce baseline total nitrogen loads delivered to rivers and streams within the basin by 19 percent by treating acres with a “high” level of treatment need. Treating ALL under-treated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline nitrogen loads delivered to rivers and streams within the basin by 41 percent.

The bottom map shows that the use of conservation practices on cropland has reduced ***total nitrogen loads delivered to the Mississippi River from all sources*** by 15 percent from conditions that would be expected without conservation practices. Application of additional conservation practices would reduce baseline total nitrogen loads delivered to the Mississippi River by 9 percent by treating acres with a “high” level of treatment need. Treating ALL under-treated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline nitrogen loads delivered to the Mississippi River by 20 percent.

Total phosphorus loss

In figure 94, the top map shows that the use of conservation practices has reduced ***total phosphorus loads delivered from cropland to rivers and streams*** within the basin by 32 percent from conditions that would be expected without conservation practices. Application of additional conservation practices would reduce baseline total phosphorus loads delivered to rivers and streams by 26 percent by treating acres with a “high” level of treatment need. Treating ALL under-treated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline phosphorus loads delivered to rivers and streams within the basin by 58 percent.

The bottom map shows that the use of conservation practices on cropland has reduced ***total phosphorus loads delivered to the Mississippi River from all sources*** by 21 percent from conditions that would be expected without conservation practices. Application of additional conservation practices would reduce baseline total phosphorus loads delivered to the Mississippi River by 13 percent by treating acres with a “high” level of treatment need. Treating ALL under-treated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline phosphorus loads delivered to the Mississippi River by 31 percent.

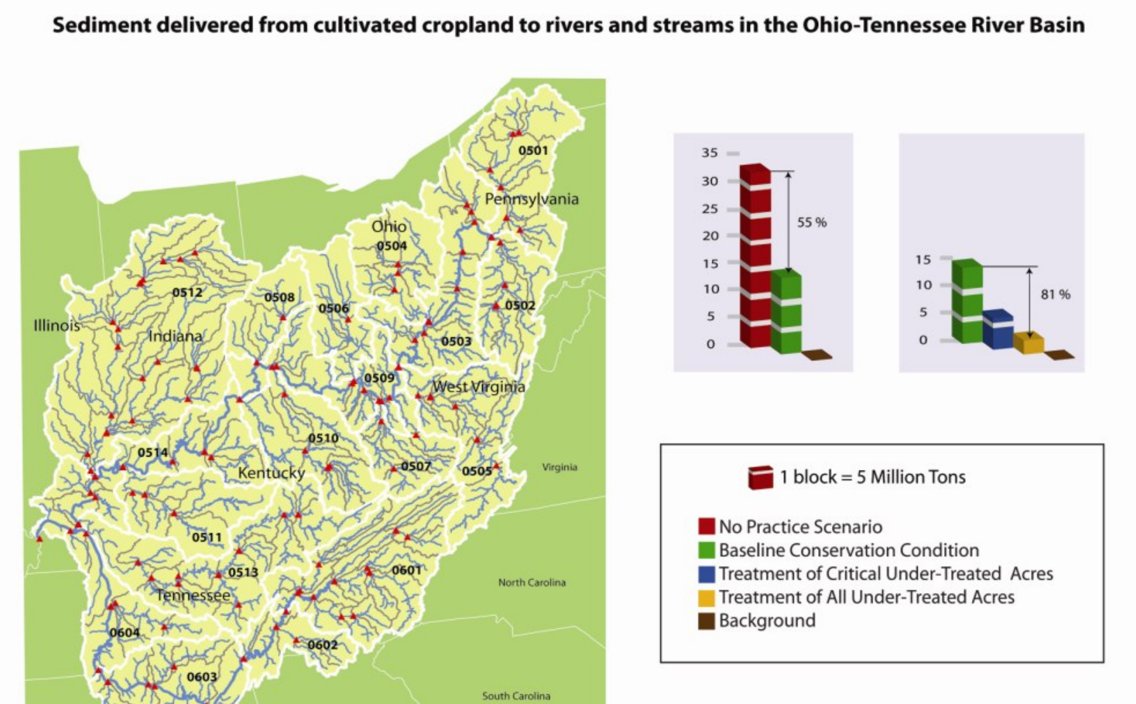
Atrazine loss

Although the full suite of pesticides was modeled for edge-of-field losses, atrazine was the only pesticide for which instream loads were assessed because it was the dominant contributor to mass loss of pesticide residues from farm fields and the primary contributor to environmental risk from pesticides in the region. Cultivated cropland was the only source for atrazine in the model simulations.

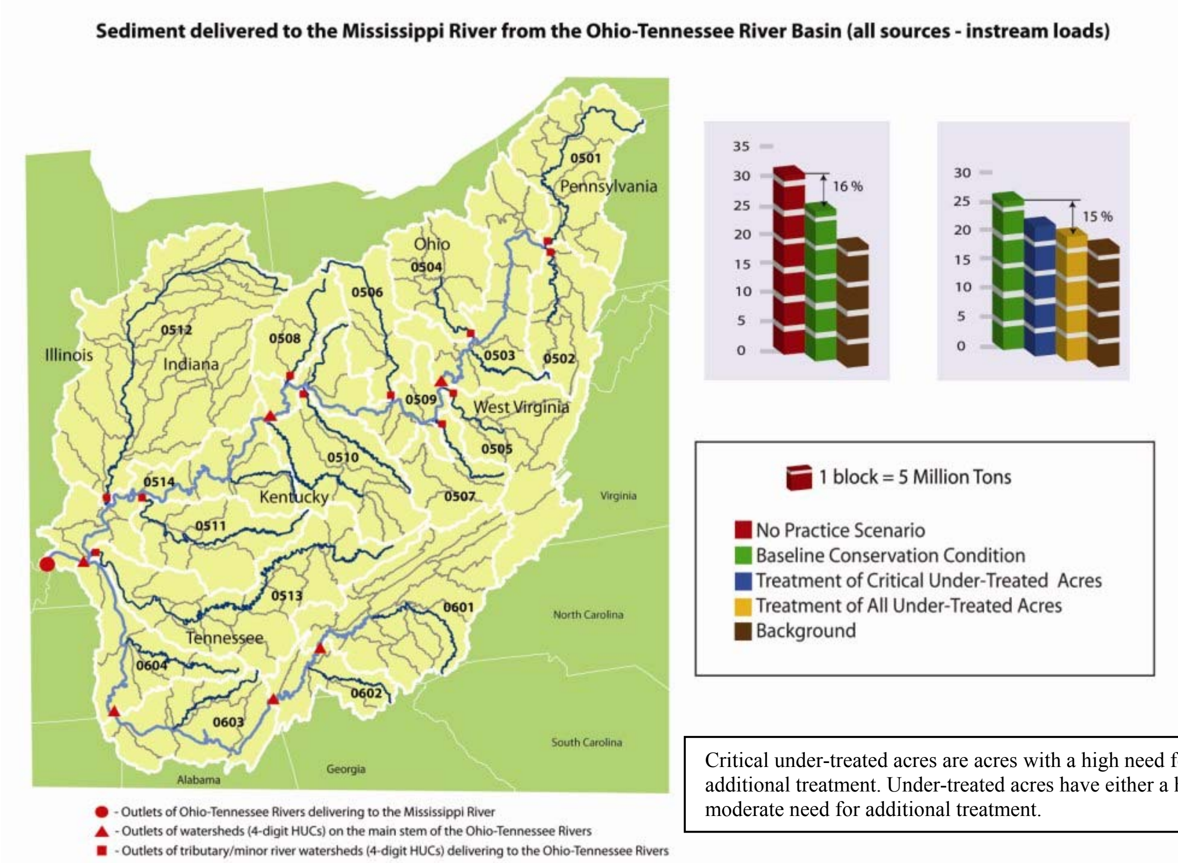
The use of conservation practices has reduced ***atrazine loads delivered from cropland to rivers and streams*** within the basin by 18 percent from conditions that would be expected without conservation practices. The use of conservation practices on cropland has also reduced ***atrazine loads delivered to the Mississippi River*** by 18 percent.

Application of additional erosion control and nutrient management conservation practices would reduce baseline atrazine loads delivered to the Mississippi River by 4 percent by treating acres with a “high” level of treatment need. Treating ALL under-treated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline atrazine loads delivered to the Mississippi River by 11 percent.

Figure 92. Summary of the effects of conservation practices on sediment loads in the Ohio-Tennessee River Basin

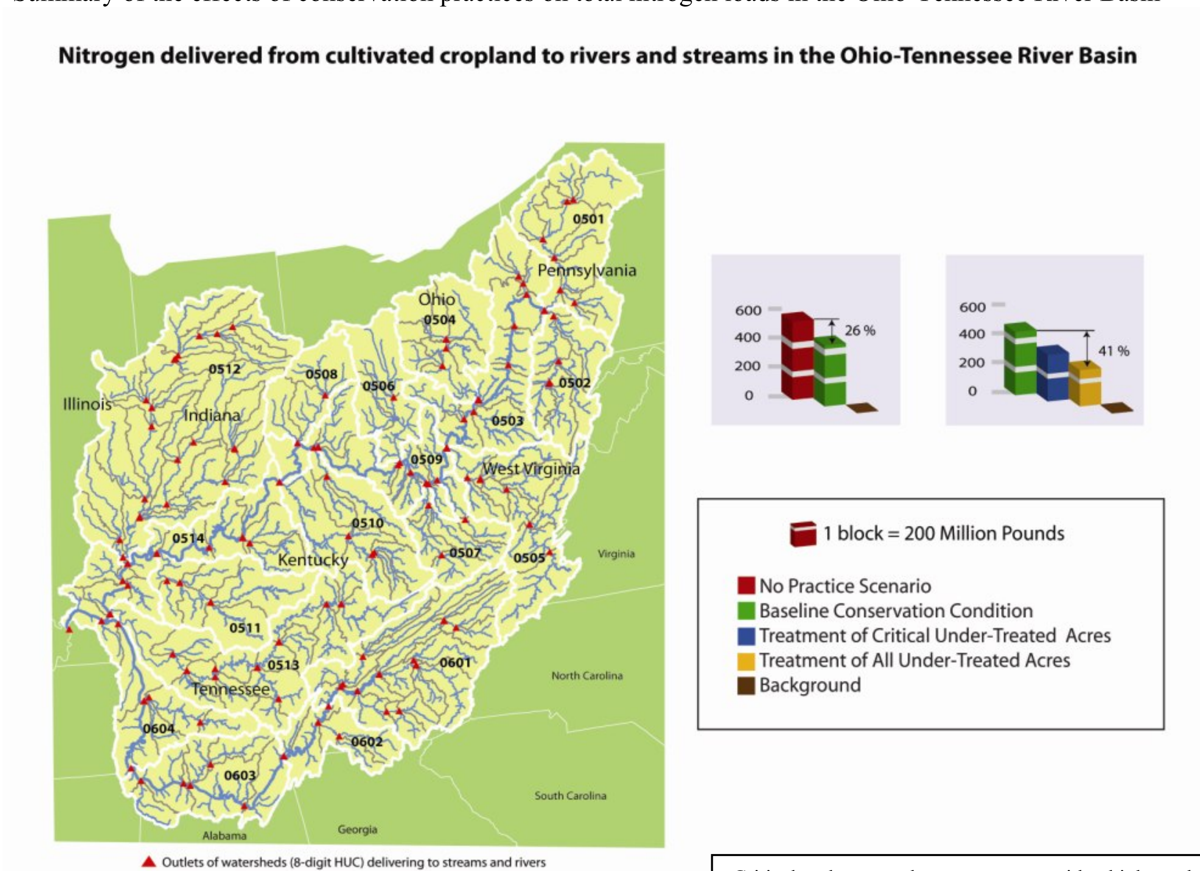


Critical under-treated acres are acres with a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

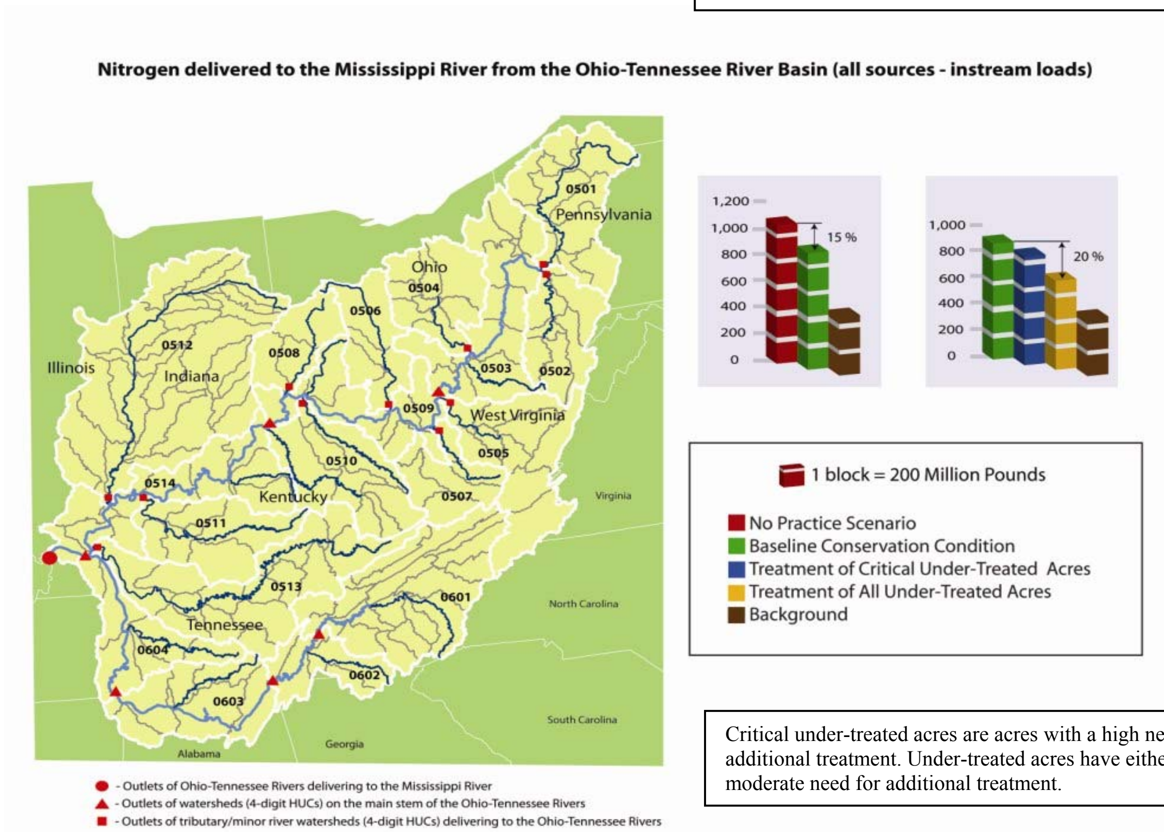


Critical under-treated acres are acres with a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

Figure 93. Summary of the effects of conservation practices on total nitrogen loads in the Ohio-Tennessee River Basin

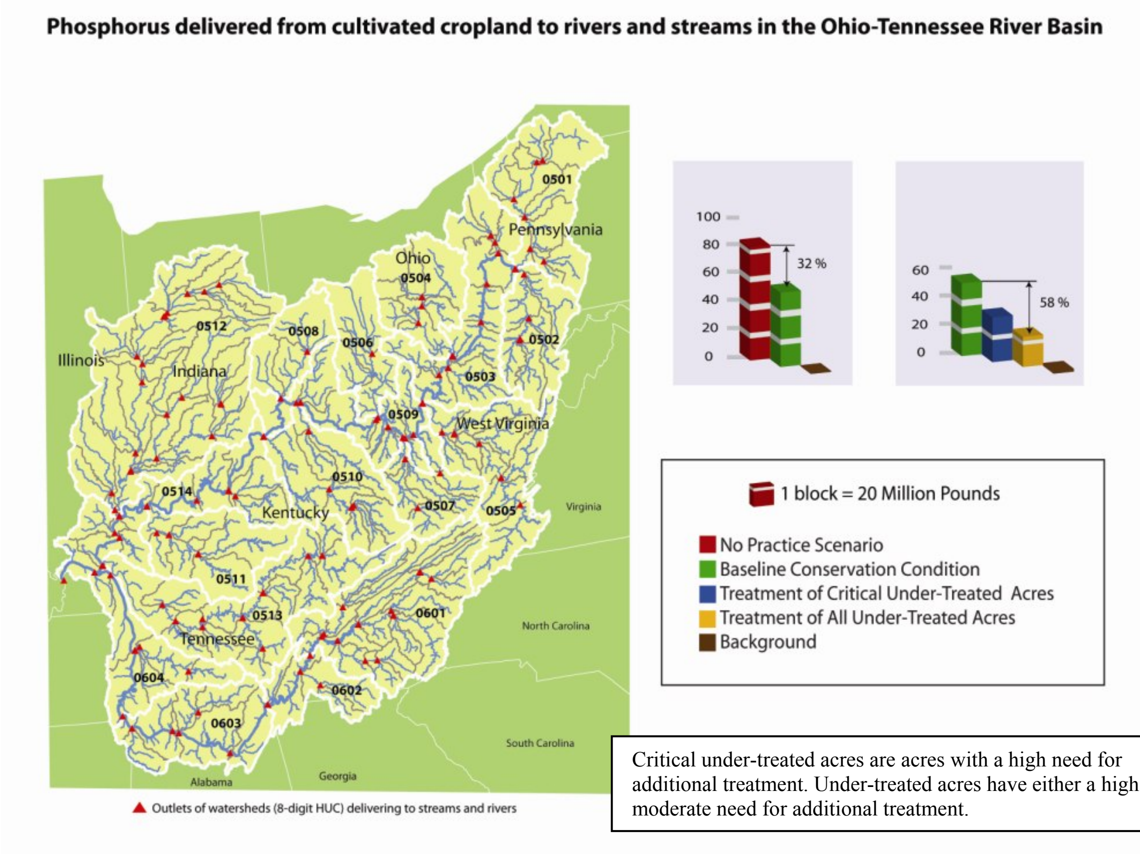


Critical under-treated acres are acres with a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

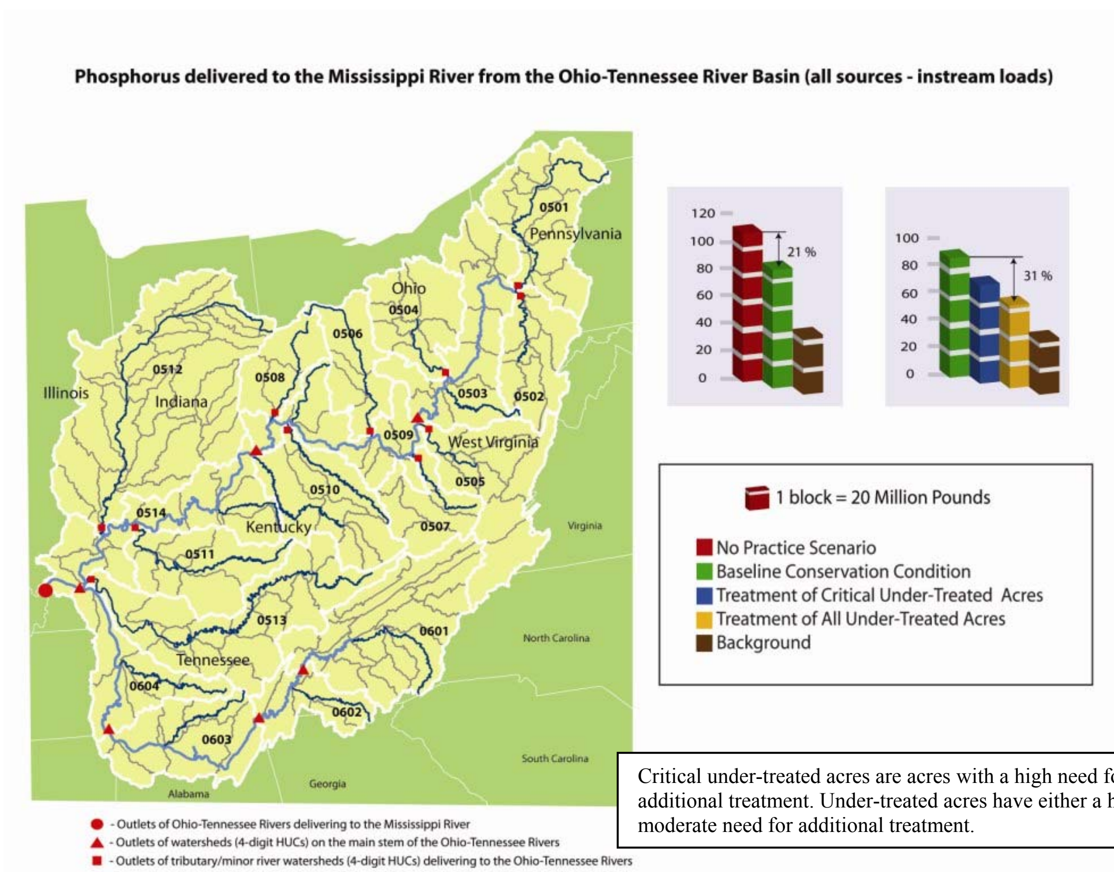


Critical under-treated acres are acres with a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

Figure 94. Summary of the effects of conservation practices on total phosphorus loads in the Ohio-Tennessee River Basin



Critical under-treated acres are acres with a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.



Critical under-treated acres are acres with a high need for additional treatment. Under-treated acres have either a high or moderate need for additional treatment.

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Appendix A: Estimates of Margins of Error for Selected Acre Estimates

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample. (Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.)
The sample for cropped acres consists of 2,124 sample points in the Ohio-Tennessee River Basin. Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with statistical sampling.

Statistics derived from the CEAP database are based upon data collected at sample sites located across all parts of the region. This means that estimates of acreage are statistical estimates and contain some amount of statistical uncertainty. Since the NRI employs recognized statistical methodology, it is possible to quantify this statistical uncertainty.

Margins of error are provided in table A1 for selected acres estimates found elsewhere in the report. The margin of error is a commonly used measure of statistical uncertainty and can be used to construct a 95-percent confidence interval for an estimate. The lower bound of the confidence interval is obtained by subtracting the margin of error from the estimate; adding the margin of error to the estimate forms the upper bound. Measures of uncertainty (e.g., margins of error, standard errors, confidence intervals, coefficients of variation) should be taken into consideration when using CEAP acreage estimates. The margin of error is calculated by multiplying the standard error by the factor 1.96; a coefficient of variation is the relative standard for an estimate, usually in terms of percentages, and is calculated by taking 100 times the standard error and then dividing by the estimate.

The precision of CEAP acres estimates depends upon the number of samples within the region of interest, the distribution of the resource characteristics across the region, the sampling procedure, and the estimation procedure. Characteristics that are common and spread fairly uniformly over an area can be estimated more precisely than characteristics that are rare or unevenly distributed.

For reporting, results for some subregions were combined because of small sample sizes.

Table A1. Margins of error for acre estimates based on the CEAP sample

	Estimated acres	Margin of error
Cropped Acres		
Allegheny and Monongahela River subregions (codes 0501, 0502)	504,600	119,341
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	534,300	100,139
Muskingum River subregion (code 0504)	1,018,300	212,014
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	1,994,300	249,673
Great Miami subregion (code 0508)	1,851,200	351,628
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	984,200	252,157
Licking-Kentucky and Green River subregions (codes 0510, 0511)	1,290,300	218,908
Wabash-Patoka-White River subregion (code 0512)	12,943,300	651,467
Upper and Lower Cumberland River subregion (code 0513)	813,600	172,106
Lower Ohio-Salt River subregion (code 0514)	1,789,200	219,666
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	938,000	175,310
Lower Tennessee including Duck River subregion (code 0604)	377,600	88,959
Total for Ohio-Tennessee River Basin	25,038,900	761,337

Table A1—continued.

	Estimated acres	Margin of error
Highly erodible land (HEL)		
Allegheny and Monongahela River subregions (codes 0501, 0502)	392,862	96,322
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	305,081	104,819
Muskingum River subregion (code 0504)	485,626	179,905
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	435,317	149,103
Great Miami subregion (code 0508)	566,329	158,915
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	278,882	126,563
Licking-Kentucky and Green River subregions (codes 0510, 0511)	536,347	117,411
Wabash-Patoka-White River subregion (code 0512)	1,812,317	355,134
Upper and Lower Cumberland River subregion (code 0513)	475,698	146,803
Lower Ohio-Salt River subregion (code 0514)	817,516	156,095
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	388,172	108,236
Lower Tennessee including Duck River subregion (code 0604)	162,822	58,038
Total for Ohio-Tennessee River Basin	6,656,969	464,253
Acres receiving manure		
Allegheny and Monongahela River subregions (codes 0501, 0502)	219,569	91,858
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503)	94,931	52,228
Muskingum River subregion (code 0504)	304,148	171,237
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507)	150,678	92,310
Great Miami subregion (code 0508)	215,428	113,395
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509)	52,236	43,513
Licking-Kentucky and Green River subregions (codes 0510, 0511)	66,554	50,720
Wabash-Patoka-White River subregion (code 0512)	854,865	253,058
Upper and Lower Cumberland River subregion (code 0513)	64,873	45,864
Lower Ohio-Salt River subregion (code 0514)	56,193	47,068
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603)	38,376	37,640
Lower Tennessee including Duck River subregion (code 0604)	27,178	41,864
Total for Ohio-Tennessee River Basin	2,145,030	342,188
Cropping Systems (table 5)		
Corn-soybean only	17,174,590	716,296
Corn-soybean with close grown crops	2,372,131	367,677
Corn only	1,329,155	365,622
Soybean only	1,307,786	256,013
Soybean-wheat only	479,505	148,445
Corn and close grown crops	410,258	153,805
Hay-crop mix	1,030,933	246,503
Remaining mix of crops	934,543	201,019
Use of structural practices (table 6)		
Overland flow control practices	3,878,027	417,126
Concentrated flow control practices	6,547,412	737,107
Edge-of-field buffering and filtering practices	2,597,511	463,862
One or more water erosion control practices	9,957,568	806,141
Wind erosion control practices	472,360	135,955
Use of cover crops	454,467	158,452
Use of residue and tillage management (table 7)		
Average annual tillage intensity for crop rotation meets criteria for no-till	12,987,141	664,601
Average annual tillage intensity for crop rotation meets criteria for mulch till	10,324,878	681,284
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	711,138	266,313
Continuous conventional tillage in every year of crop rotation	1,015,743	273,896

Table A1—continued.

	Estimated acres	Margin of error
Use of structural practices and/or residue and tillage management (table 8)		
No-till or mulch till with carbon gain, no structural practices	9,898,051	737,205
No-till or mulch till with carbon loss, no structural practices	4,276,097	426,524
Some crops with reduced tillage, no structural practices	399,362	176,747
Structural practices and no-till or mulch till with carbon gain	5,838,361	664,434
Structural practices and no-till or mulch till with carbon loss	3,299,511	327,204
Structural practices and some crops with reduced tillage	311,776	147,458
Structural practices only	507,921	226,167
No water erosion control treatment	507,822	154,726
Conservation treatment levels for structural practices (fig. 7)		
High level of treatment	1,380,374	316,219
Moderately high level of treatment	2,473,268	345,303
Moderate level of treatment	6,103,926	643,052
Low level of treatment	15,081,332	858,497
Conservation treatment levels for residue and tillage management (fig. 8)		
High level of treatment	14,811,088	735,520
Moderately high level of treatment	944,399	235,953
Moderate level of treatment	8,701,371	514,887
Low level of treatment	582,042	178,407
Conservation treatment levels for nitrogen management (fig. 9)		
High level of treatment	3,575,415	439,675
Moderately high level of treatment	7,021,662	631,563
Moderate level of treatment	10,614,187	693,064
Low level of treatment	3,827,636	549,423
Conservation treatment levels for phosphorus management (fig. 10)		
High level of treatment	5,421,911	647,955
Moderately high level of treatment	5,402,689	544,707
Moderate level of treatment	3,292,588	398,015
Low level of treatment	10,921,713	838,177
Conservation treatment levels for IPM (fig. 11)		
High level of treatment	1,193,272	358,047
Moderate level of treatment	9,731,062	637,215
Low level of treatment	14,114,566	786,452
Conservation treatment levels for water erosion control practices (fig. 49)		
High level of treatment	12,208,607	917,181
Moderately high level of treatment	2,265,472	292,352
Moderate level of treatment	7,855,173	555,362
Low level of treatment	2,709,648	415,072
Conservation treatment levels for nitrogen runoff control (fig. 50)		
High level of treatment	1,502,504	320,295
Moderately high level of treatment	10,711,905	758,574
Moderate level of treatment	10,798,764	609,421
Low level of treatment	2,025,727	341,828
Conservation treatment levels for phosphorus runoff control (fig. 51)		
High level of treatment	2,572,645	386,301
Moderately high level of treatment	6,799,251	689,270
Moderate level of treatment	11,765,189	647,062
Low level of treatment	3,901,815	459,503

Table A1—continued.

	Estimated acres	Margin of error
Soil runoff potential (fig. 52)		
High	2,200,218	329,753
Moderately high	7,213,189	630,090
Moderate	3,111,564	455,165
Low	12,513,929	946,097
Soil leaching potential (fig. 54)		
High	714,179	189,171
Moderately high	1,384,277	280,506
Moderate	19,791,016	662,642
Low	3,149,428	437,928
Level of conservation treatment need by resource concern		
Sediment loss (table 23)		
High (critical under-treated)	3,382,139	466,122
Moderate (non-critical under-treated)	2,934,571	457,604
Low (adequately treated)	18,722,190	954,430
Nitrogen loss with surface runoff (sediment attached and soluble) (table 24)		
High (critical under-treated)	3,105,446	415,435
Moderate (non-critical under-treated)	4,090,370	453,345
Low (adequately treated)	17,843,084	1,027,668
Nitrogen loss in subsurface flows (table 25)		
High (critical under-treated)	451,346	146,729
Moderate (non-critical under-treated)	3,898,996	508,224
Low (adequately treated)	20,688,558	757,510
Phosphorus lost to surface water (table 26)		
High (critical under-treated)	4,947,847	500,944
Moderate (non-critical under-treated)	10,892,266	733,954
Low (adequately treated)	9,198,787	802,074
Level of conservation treatment need for one or more resource concerns		
Ohio-Tennessee River Basin (table 30)		
High (critical under-treated)	6,012,285	567,724
Moderate (non-critical under-treated)	11,505,660	748,034
Low (adequately treated)	7,520,955	797,723
Allegheny and Monongahela River subregions (codes 0501, 0502) (table 30)		
High (critical under-treated)	355,307	132,933
Moderate (non-critical under-treated)	124,011	77,505
Low (adequately treated)	25,282	26,835
Upper Ohio-Beaver-Little Kanawha River subregion (code 0503) (table 30)		
High (critical under-treated)	224,912	95,030
Moderate (non-critical under-treated)	199,834	86,864
Low (adequately treated)	109,555	52,956
Muskingum River subregion (code 0504) (table 30)		
High (critical under-treated)	512,284	171,466
Moderate (non-critical under-treated)	268,635	128,572
Low (adequately treated)	237,381	132,561
Scioto, Kanawha, and Guyandotte-Big Sandy River subregions (codes 0505, 0506, 0507) (table 30)		
High (critical under-treated)	354,965	133,826
Moderate (non-critical under-treated)	1,046,397	232,026
Low (adequately treated)	592,938	208,327

Table A1—continued.

	Estimated acres	Margin of error
Level of conservation treatment need for one or more resource concerns--continued		
Great Miami subregion (code 0508) (table 30)		
High (critical under-treated)	395,717	145,775
Moderate (non-critical under-treated)	867,241	257,054
Low (adequately treated)	588,242	215,563
Middle Ohio-Raccoon-Little-Miami River subregion (code 0509) (table 30)		
High (critical under-treated)	214,538	99,825
Moderate (non-critical under-treated)	453,444	148,898
Low (adequately treated)	316,218	166,900
Licking-Kentucky and Green River subregions (codes 0510, 0511) (table 30)		
High (critical under-treated)	389,868	109,245
Moderate (non-critical under-treated)	699,776	148,141
Low (adequately treated)	200,655	107,479
Wabash-Patoka-White River subregion (code 0512) (table 30)		
High (critical under-treated)	2,076,579	410,361
Moderate (non-critical under-treated)	6,168,764	572,961
Low (adequately treated)	4,697,957	564,921
Upper and Lower Cumberland River subregion (code 0513) (table 30)		
High (critical under-treated)	226,962	75,142
Moderate (non-critical under-treated)	492,695	149,038
Low (adequately treated)	93,942	82,614
Lower Ohio-Salt River subregion (code 0514) (table 30)		
High (critical under-treated)	735,134	133,876
Moderate (non-critical under-treated)	637,962	160,998
Low (adequately treated)	416,104	127,127
Upper and Middle Tennessee River subregions (codes 0601, 0602, 0603) (table 30)		
High (critical under-treated)	385,603	105,976
Moderate (non-critical under-treated)	338,508	107,767
Low (adequately treated)	213,888	141,669
Lower Tennessee including Duck River subregion (code 0604) (table 30)		
High (critical under-treated)	140,415	59,505
Moderate (non-critical under-treated)	208,392	73,627
Low (adequately treated)	28,792	24,151

Appendix B: Model Simulation Results for the Baseline Conservation Condition for Subregions in the Ohio-Tennessee River Basin

Model simulation results presented in Chapter 4 for the baseline conservation condition are presented in tables B1–B5 for the subregions in the Ohio-Tennessee River Basin. For reporting, results for some subregions were combined because of small sample sizes. The column headings refer to the 4-digit Hydrologic Unit Codes (HUC), as shown below:

Subregion code	Subregion name
0501 and 0502	Allegheny and Monongahela River subregions
503	Upper Ohio-Beaver-Little Kanawha River subregion
504	Muskingum River subregion
0505, 0506, and 0507	Scioto, Kanawha, and Guyandotte-Big Sandy River subregions
508	Great Miami subregion
509	Middle Ohio-Raccoon-Little-Miami River subregion
0510 and 0511	Licking-Kentucky and Green River subregions)
512	Wabash-Patoka-White River subregion
513	Upper and Lower Cumberland River subregion
514	Lower Ohio-Salt River subregion
0601, 0602, and 0603	Upper and Middle Tennessee River subregions
604	Lower Tennessee including Duck River subregion

Table B1. Basin characteristics and average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Ohio-Tennessee River Basin

Model simulated outcome	Ohio-Tennessee River Basin	0501 and 0502	0503	0504	0505, 0506 and 0507	0508	0509	0510 and 0511	0512	0513	0514	0601, 0602 and 0603	0604
CEAP sample size for estimating cropped acres	2,124	56	63	85	128	175	137	153	853	90	249	78	57
Cropped acres (million acres)	25.039	0.505	0.534	1.018	1.994	1.851	0.984	1.290	12.943	0.814	1.789	0.938	0.378
Percent of acres in region	100%	2%	2%	4%	8%	7%	4%	5%	52%	3%	7%	4%	2%
Percent of acres highly erodible	27%	78%	57%	48%	22%	31%	28%	42%	14%	58%	46%	41%	43%
Percent of acres irrigated	1%	0%	0%	0%	1%	0%	1%	3%	1%	0%	2%	1%	2%
Percent of acres receiving manure	9%	44%	18%	30%	8%	12%	5%	5%	7%	8%	3%	4%	7%
Water sources (average annual inches)													
Non-irrigated acres	42	44	39	39	39	39	42	48	40	51	46	55	53
Precipitation													
Irrigated acres	43	NA	NA	NA	40	NA	42	46	41	NA	46	57	52
Precipitation	11	NA	NA	NA	12	NA	12	14	10	NA	8	19	21
Irrigation water applied	42	44	39	39	39	39	42	48	40	51	46	55	53
Water loss pathways (average annual inches)													
Evapotranspiration	25.5	24.2	24.1	23.8	24.4	23.8	25.2	27.4	25.0	28.6	26.3	33.8	32.2
Surface water runoff	7.6	9.2	6.2	5.8	5.8	6.4	7.7	10.9	7.0	12.0	10.2	10.8	10.6
Subsurface water flow	9.3	10.5	9.4	10.0	8.9	9.1	9.5	10.3	8.9	10.4	9.8	10.8	10.7
Erosion and sediment loss (average annual tons/acre)													
Wind erosion	0.02	0.02	0.01	0.02	0.01	0.00	0.00	0.01	0.03	0.00	0.02	0.01	0.01
Sheet and rill erosion	1.14	2.26	1.17	1.14	0.55	0.95	0.86	1.96	0.84	2.39	2.20	1.96	2.27
Sediment loss at edge of field due to water erosion	1.59	4.55	1.70	1.89	0.60	1.09	1.32	2.90	1.05	2.84	3.82	2.55	3.24
Soil organic carbon (average annual pounds/acre)													
Loss of soil organic carbon with wind and water erosion	258	342	231	221	178	224	283	368	221	460	457	283	302
Change in soil organic carbon, including loss of carbon with wind and water erosion	27	-154	-35	-18	52	45	21	-11	56	-14	-42	-38	-39

Table B2. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Ohio-Tennessee River Basin

Model simulated outcome	Ohio-Tennessee River Basin	0501 and 0502	0503	0504	0505, 0506 and 0507	0508	0509	0510 and 0511	0512	0513	0514	0601, 0602 and 0603	0604
Nitrogen (average annual pounds/acre)													
Nitrogen sources													
Atmospheric deposition	8.4	10.1	9.7	8.9	8.4	8.0	8.4	8.1	8.5	8.1	8.2	8.3	8.2
Bio-fixation by legumes	64.3	22.0	46.9	55.4	73.7	71.7	82.8	52.9	68.8	48.1	64.5	28.6	41.8
Nitrogen applied as commercial fertilizer and manure	83.8	105.5	83.6	74.6	74.6	79.2	74.9	101.9	80.4	130.8	88.7	90.8	86.0
All nitrogen sources	156.5	137.5	140.2	138.9	156.6	158.9	166.2	162.9	157.7	187.0	161.3	127.7	136.0
Nitrogen in crop yield removed at harvest	114.2	94.0	100.1	102.2	116.9	114.2	123.4	114.0	117.9	125.4	114.5	80.4	87.6
Nitrogen loss pathways													
Nitrogen loss by volatilization	7.5	4.7	7.4	7.4	8.6	8.7	9.6	8.1	7.0	9.7	7.6	7.0	7.7
Nitrogen loss through denitrification	2.5	1.7	2.1	1.9	2.6	2.3	3.4	2.6	2.6	3.4	2.6	1.5	1.4
Nitrogen lost with windborne sediment	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.1
Nitrogen loss with surface runoff , including waterborne sediment	13.2	24.7	13.6	12.6	8.3	10.9	13.9	19.9	10.3	28.9	24.9	15.7	16.5
Nitrogen loss in subsurface flow pathways	19.2	28.7	21.1	17.9	17.0	20.9	15.5	21.8	18.2	22.3	17.4	27.9	27.3
Total nitrogen loss for all loss pathways	42.6	59.9	44.2	39.8	36.5	42.8	42.3	52.4	38.3	64.3	52.7	52.1	52.9
Change in soil nitrogen	-1.8	-18.4	-6.5	-5.0	1.8	0.6	-0.7	-4.5	0.2	-4.8	-8.1	-6.1	-5.5

Table B3. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Ohio-Tennessee River Basin

Model simulated outcome	Ohio-Tennessee River Basin	0501 and 0502	0503	0504	0505, 0506 and 0507	0508	0509	0510 and 0511	0512	0513	0514	0601, 0602 and 0603	0604
Phosphorus (average annual pounds/acre)													
Phosphorus applied as commercial fertilizer and manure	24.4	31.5	21.6	23.5	22.8	22.3	24.8	28.1	23.8	32.6	25.8	25.0	24.2
Phosphorus in crop yield removed at harvest	17.9	17.0	15.6	16.2	17.9	17.7	18.7	17.7	18.5	20.7	17.8	12.9	13.4
Phosphorus loss pathways													
Phosphorus lost with windborne sediment	0.04	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.06	0.00	0.02	0.02	0.01
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	4.52	8.02	3.70	3.56	3.08	3.46	4.51	6.90	3.68	8.79	7.35	7.36	7.27
Soluble phosphorus loss to groundwater	0.03	0.06	0.03	0.04	0.01	0.02	0.03	0.04	0.02	0.05	0.04	0.07	0.07
Total phosphorus loss for all loss pathways	4.58	8.12	3.75	3.63	3.10	3.49	4.55	6.96	3.76	8.84	7.40	7.45	7.35
Change in soil phosphorus	1.7	6.1	1.6	3.5	1.6	0.9	1.4	3.1	1.3	2.5	0.0	4.2	3.2
Pesticides													
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1827	1588	1277	1639	1779	1844	1907	1535	1830	2164	1934	2335	1779
Pesticide loss													
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	28	31	11	18	19	29	27	28	25	62	48	29	26
Edge-of-field pesticide risk indicator													
Average annual surface water pesticide risk indicator for aquatic ecosystem	4.4	2.6	1.7	2.2	2.3	4.5	3.3	2.8	4.3	22.1	4.6	2.8	2.1
Average annual surface water pesticide risk indicator for humans	0.9	0.6	0.4	0.5	0.6	1.1	0.9	0.7	1.0	2.1	1.3	0.9	0.6
Average annual groundwater pesticide risk indicator for humans	0.2	0.4	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.3	0.2	0.6	0.4

Table B4. Percent of cropped acres for conservation treatment levels and soil vulnerability potentials, by subregion, in the Ohio-Tennessee River Basin

Category	0501 and 0502	0503	0504	0505, 0506 and 0507	0508	0509	0510 and 0511	0512	0513	0514	0601, 0602 and 0603	0604
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 7)												
High conservation treatment level	5	6	6	8	5	6	4	4	7	8	10	9
Moderately-high conservation treatment level	36	13	9	6	8	7	20	9	14	10	7	11
Moderate conservation treatment level	43	31	20	19	24	29	35	21	36	29	33	21
Low conservation treatment level	16	50	65	67	62	58	41	65	43	54	50	59
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 8)												
High conservation treatment level	9	28	39	72	66	65	44	69	50	38	30	30
Moderately-high conservation treatment level	6	5	6	3	3	1	5	4	3	2	3	5
Moderate conservation treatment level	71	61	55	25	30	34	47	25	47	59	57	60
Low conservation treatment level	14	6	1	1	1	0	5	2	0	2	10	5
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 9)												
High conservation treatment level	21	21	26	16	15	14	15	13	3	12	18	10
Moderately-high conservation treatment level	31	33	38	32	26	27	34	28	27	23	17	13
Moderate conservation treatment level	41	28	28	33	35	43	43	42	54	56	53	66
Low conservation treatment level	6	18	7	19	24	16	8	16	16	9	12	11
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 10)												
High conservation treatment level	21	37	28	25	28	17	12	23	8	17	11	7
Moderately-high conservation treatment level	3	14	16	19	17	23	24	26	12	18	5	13
Moderate conservation treatment level	29	22	19	9	13	11	19	10	14	16	33	20
Low conservation treatment level	46	27	36	47	42	48	45	41	66	49	52	60
Percent of cropped acres within subregion at four conservation treatment levels of soil runoff potential (see figure 52)												
High soil vulnerability potential	42	21	26	5	9	8	17	3	13	22	9	3
Moderately high soil vulnerability potential	29	55	44	33	40	29	33	22	46	31	27	39
Moderate soil vulnerability potential	11	6	2	16	8	29	9	14	10	8	11	6
Low soil vulnerability potential	18	18	28	46	43	34	42	60	31	39	52	52
Percent of cropped acres within subregion at four conservation treatment levels of soil leaching potential (see figure 54)												
High soil vulnerability potential	28	0	0	1	1	0	0	4	1	1	3	0
Moderately high soil vulnerability potential	29	26	17	2	3	<1	2	4	8	1	18	12
Moderate soil vulnerability potential	39	64	80	83	85	68	88	78	83	90	76	78
Low soil vulnerability potential	3	10	2	14	11	31	11	14	8	8	3	10

Note: Percents may not add to 100 within categories due to rounding.

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Ohio-Tennessee River Basin

Category	0501 and 0502	0503	0504	0505, 0506 and 0507	0508	0509	0510 and 0511	0512	0513	0514	0601, 0602 and 0603	0604
Percent of cropped acres within subregion with conservation treatment needs for sediment loss												
High level of treatment need	45	30	34	8	16	14	18	8	18	28	15	14
Moderate level of treatment need	19	25	22	15	18	11	18	7	17	14	12	12
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff												
High level of treatment need	39	29	30	7	13	12	17	7	17	28	16	11
Moderate level of treatment need	26	36	30	21	24	14	23	11	32	22	9	22
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water												
High level of treatment need	58	38	42	14	17	20	29	12	26	37	40	35
Moderate level of treatment need	31	36	28	49	44	45	50	44	62	39	35	56
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows												
High level of treatment need	21	0	0	1	0	0	0	2	1	0	1	0
Moderate level of treatment need	12	24	11	17	21	12	9	16	17	9	21	19
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern												
High level of treatment need	70	42	50	18	21	22	30	16	28	41	41	37
Moderate level of treatment need	25	37	26	52	47	46	54	48	61	36	36	55
Under-treated (high or moderate level of treatment need)	95	79	77	70	68	68	84	64	88	77	77	92